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PART-TASK TRAINING STRATEGIES IN SIMULATED CARRIER LANDING FINAL APPROACH TRAINING

Dennis C. Wightman
Human Factors Laboratory
Naval Training Equipment Center
Orlando, FL 32813

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This experiment manipulated task simplification variables of lag and approach length in order to examine their influence on training of the perceptual motor skills of a simulated carrier landing in the transfer of a training experiment. In addition, the subject's level of motor skills was assessed as a means of controlling r individual differences and testing for any interactions that might exist between the training strategies and the subject's aptitude.

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Strong transfer effects were found for both motor-skill levels and the segmentation technique, while lag manipulation produced no main effects. Several interactions of the aptitude by treatment type between subjects' motor-skill levels and training manipulation were discovered.

The lag by motor-skill interaction showed that subjects with low motor-skills who were trained by progressive lag manipulation performed most poorly upon transfer of a training experiment. The blocks by task and by motor-skill interaction indicated the poorest transferred performance was exhibited by the low-motor-skill subjects trained by the whole-task method.

Part-task training and backward chaining expl nations were offered for the segmentation method's effect. The motor skills by treatment interactions implied that the effects of training manipulations differed depending upon the motor-skill category of the subject. While the lag manipulation made no difference to the transfer performance of the high-motor-skill subjects, it had a negative influence on the performance of low-motor-skill subjects. The segmentation manipulation also proved to exert its differential influence dependent upon the subject's motor-skill category. While high-motor-skill subjects quickly overcame the negative influence of whole-task training, the low-motor-skill subjects could not. These results imply that the value of the segmentation manipulation was especially great for the training of low-motor-skill subjects.

The ~~These~~ results suggest that low-motor-skill subjects are unable to adapt to changes presented during training and are unable to break bad habits acquired during the course of training.

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SECTION I

INTRODUCTION

Research into pilot training and the use of flight simulation in pilot training programs has received a large amount of attention in the recent past. However, the notion that the value of flight simulation may be enhanced when principles of learning are translated into training techniques is just beginning to be addressed. The research reported here investigated the impact of certain basic variables in an effort to increase the training potential of the flight simulator for training an operationally relevant task.

SIMULATION IN PILOT TRAINING

Research conducted on the Advanced Simulator for Pilot Training (ASPT) at Williams Air Force Base, Arizona, and on the Visual Technology Research Simulator (VTRS) at the Naval Training Equipment Center in Orlando, Florida, has addressed these issues. The application of such learning tools as the simulator's record/playback feature (Hughes, Hannan and Jones, 1979) and the use of backward chaining (Bailey, Hughes, and Jones, 1980) have been explored on the ASPT. The applicability of the simulator's freeze feature to carrier landing training (Hughes, Lintern, Wightman, and Brooks, 1981) and the use of unusual perspective views to train perceptual and control skills for straight and level flight (Hennessy, Lintern, and Collyer, 1981) are issues that have been addressed in experiments on the VTRS. These studies represent initial attempts to explore the potential of flight simulators as training devices through the application of principles of learning. The research proposed here is based on this point of view.

THIS EXPERIMENT

The primary concern of the experiment reported here is with part-task training. The literature concerning the use of part versus whole training for perceptual-motor skills has been reviewed by Wightman and Lintern (1983). In their review, the theoretical and applied value of various part-task strategies for enhanced acquisition and improved transfer were addressed and this experiment was carried out to clarify some of the issues they addressed. Of major interest was the effect on transfer of training for these manipulations for a complex perceptual-motor task. In addition to task variable manipulations, individual differences in motor skills were examined in order to explore possible interactions with the task variable manipulated in the training situation.

CRITIQUES OF PERCEPTUAL-MOTOR SKILLS TRAINING RESEARCH

Goldstein (1980) in a review of research relevant to training in organizational settings pointed out the shortcomings of such research. The haphazard, disorganized nature of research on training techniques was one area of concern. To correct this state of affairs, Goldstein suggested that more research be conducted focusing upon organizationally relevant tasks which take into account the nature of the task to be performed, the learning required to perform the task, and the training technique that will best yield the required

learning. One can conceive of flying tasks as continuous, perceptual- motor tasks characterized by complex multidimensional tracking. Following Goldstein's suggestion, one should look for training techniques suggested by learning principles developed from research on perceptual-motor learning. Unfortunately, as lamented by some motor learning researchers (e.g., Singer, 1978), little of what has been developed in the motor learning laboratory has been used in the training sphere. This is in no small measure due to the sterile, abstracted nature of the motor behaviors selected for study in laboratory experiments. Frequently, motor skills such as lever positioning or slide movements are used as target tasks. Aside from the obvious lack of face validity of such experimental tasks, some crucial components are absent that could be readily applied to teaching vehicle control skills. Many real-life perceptual-motor behaviors, such as vehicle control, are continuous and externally paced, rather than discrete and self-paced as are many laboratory tasks. Singer (1978) reflected the concern of many researchers in the motor learning area when he stated:

> "Research needs to be extended to more real life settings as well as to laboratory settings that come closer to the 'actual' instead of the artificial and the constrained" (p. 88).

So, both applied and basic researchers are pointing to the same sort of deficiencies in the realm of training research.

Aside from this lack of generalizability, the perceptual-motor research related to the principle of part versus whole learning has suffered because of the absence of a comprehensive conceptual framework with which to relate part versus whole learning. Frequently, assumptions are made about perceptual-motor tasks that are ill founded or accepted on faith. These problems have probably resulted from inadequate analysis of the nature of continuous perceptual-motor tasks and the dimensions along which they may be partitioned for part-task training strategies. To address this problem, Wightman and Lintern (1983) developed a conceptual framework and reviewed the research dealing with part versus whole learning of perceptual-motor tasks with an orientation suggested by this framework. Their review also provided a rationale for and a definition of part-task training.

PART VERSUS WHOLE LEARNING OF PERCEPTUAL MOTOR SKILLS

Wightman and Lintern (1983) state that part-task training is generally regarded as practice on some set of components of a whole task as a prelude to practice or performance of the whole task. The rationale for part-task practice is that whole-task performance will be more adept following practice on task components.

Pragmatically, the value of the use of part-task training strategies is two-fold. First, if practice of the critical elements of some complex motor skills can be carried out in a simulator in a manner such that total time to develop skill on the whole task can be reduced, a savings in the costs of training time can be achieved. Secondly, if certain components of the target task can be acquired in less expensive part-task trainers, a reduction in the costs of using expensive simulators can be gained.

DIMENSIONS OF PERCEPTUAL-MOTOR TASKS

Discussion of the question of part versus whole training of perceptual-motor tasks tend to skirt the issue of definition of task subdivision or what constitutes a part for implementation of a part-task training manipulation. Many researchers have chosen the expedient of saying that meaningful part-task subdivision depends upon the specific whole task in question (e.g., Naylor, 1962; Schendel, Shields, and Katz, 1978). Nevertheless, general categories of task dimensions do exist for perceptual-motor tasks that allow for a taxonomy of task features. These methods of dividing whole tasks for part-task purposes are labeled segmentation, fractionation and simplification (Wightman and Lintern, 1983).

Segmentation

When the perceptual-motor task requires performance over time or across space, as do a good many flight tasks, segments of the maneuver may be practiced in isolation. This is likely to be of particular value with converging tasks such as landing an aircraft where the error tolerances are broader earlier in the approach but become narrower toward the termination. Critical segments of the task can be practiced in the simulator to a greater extent than in the aircraft. A larger amount of practice can be provided on the most critical phase of the task (e.g., the period just before landing) than can be accomplished if the whole task were to be performed every time. The ordering of these segments and the amount of time spent on them can be determined based upon empirical evidence, behavioral principles, or both.

Fractionation

When complex perceptual-motor tasks are comprised of more than one control-display relationship, as is aircraft piloting, one method that has been employed to extract task parts has been along these natural control-display dimensions. If, for example, the whole task consists of tracking pitch and roll, the subject could be given practice on the pitch and roll components each in isolation prior to practicing the whole task. This method of task subdivision has been the predominant one used in part-whole perceptual-learning experiments.

Simplification

When perceptual-motor tasks are so complex as to be well beyond the subject's current skill level, the whole task can be simplified so that the subject can practice on a less complex version of the target task. (cf. Lintern and Gopher, 1978). The stripping away of task load features through the modification of system dynamics represents a method of simplifying tasks. The training can proceed in a fixed fashion where transfer from simple to difficult versions of the same task can be evaluated (Day, 1952, Holding, 1962). Simplification can also dictate a training method that proceeds in an adaptive fashion. Adaptive programs present the trainee with successive approximations of the whole or criterion task and continuously change task demands until the trainee is performing the whole task (Lintern and Gopher 1978).

Despite the extensive research on the three methods of partitioning tasks for part-task training of perceptual-motor skills, little direct guidance can be extracted for the purpose of training real world tasks. What is required is to focus upon which of these techniques are the most important for simulator training and to address the issues and variables that flow from them in the context of a perceptual-motor task that meets Goldstein's (1980) requirement of organizational relevance. This should lead to a more general basis for the implementation of part-task training strategies.

As mentioned previously, two conditions must be met for part-task training to be useful. First, early proficiency of trainees must be accomplished. Secondly, whatever process stimulates early proficiency must also yield maximum transfer.

The research results of the fractionation experiments indicate an interaction between task complexity and task organization. For continuous, multidimensional perceptual-motor tasks, of high component complexity and high component interdependence, fractional part-task training techniques have not been found to be as effective as whole-task training. This appears to be primarily due to the fact that these strategies do not meet the second criteria of maximum transfer. Since so many flight control tasks are of this character, the fractionation part-task method is probably not likely to yield effective training.

The simplification technique, by contrast, should prove to be a valuable method of part-task training. This is true to the extent that this method maintains the consistency of the stimulus-response relationships, provides information early in learning about proper error correction procedures and can be maximally effective when applied in a manner consistent with trainee needs.

In order to foster early proficiency, several simplification conditions may be imposed. Any condition that will provide the trainee with unambiguous error information should evoke early correct performance. Adams (1978) said that "learning...is problem solving and [knowledge of results] is information about error that tells the subject how well he is succeeding at the problem solving task. [Such] information is actively processed...and the subject forms a hypothesis about how to improve his performance... [t]his hypothesis behavior eventually drops out...when a high level of proficiency is attained" (p. 234). The simplification method can serve as a means of giving error information so as to aid the trainee in the generation of the hypothesis about how to improve performance. Adams further suggests, "that if the standard of correctness...is learned early it can be used as a source of error information for subsequent learning" (p. 237). Any information or modification to the task which supplies the standards of correctness for the task should speed the acquisition of perceptual-motor skills.

Supplying unambiguous error information in a fashion which corresponds to the way in which the trainee approaches the learning of tracking-type tasks should further enhance the early performance of the task. Current analysis of the process by which people approach the learning of tracking tasks implies a three-staged operation (Wightman and Lintern, 1983; Jaeger, Agarwal, and Gottlieb, 1980). The first stage involves determining the proper direction of

control movements to correct error conditions. In the second stage the trainee develops facility with timing of the error correction response. In essence, the trainee learns to detect error conditions which demand corrective input. In the final phase, the trainee concentrates on performing control movements of the proper magnitude for any given error condition that might develop. Matching the nature of the error information to the needs of the trainee at each stage in this process is one approach to training which should yield maximal performance early in practice.

As stated in the discussion about segmentation, practice on critical elements of the task also will lead to early proficiency. Thus, a training condition that provides unambiguous error information in a manner consistent with the trainees' needs and which allows for practice on critical segments of the task should be an efficient means of part-task training.

Once the condition of early proficiency is met, the next critical element for an effective training strategy is the facilitation of transfer. To assure maximum transfer, three general conditions must be met. First, any changes in response requirements dictated by the training technique must be accompanied by perceptible changes in stimuli. Secondly, when the task is low in intrinsic feedback, supplemental feedback associated with task modification should be provided. Thirdly, as a corollary to the need for unambiguous error information, trainees should be provided with clear information about the nature of any differences between the training and transfer tasks. A part-task training method can be structured to meet all of these requirements.

A task that represents an appropriate vehicle for manipulating training variables such as these is the simulated carrier landing task.

THE CARRIER LANDING TASK

Guiding an aircraft along the glideslope to a landing aboard an aircraft carrier is one of the most difficult tasks in aviation. Tolerance for error is small and the requirements for precision are great. The consequence of errors are sometimes catastrophic, as evidenced by the recent mishap aboard the USS Nimitz (Clausen, 1982).

The carrier landing task can be characterized as a multidimensional, perceptual-motor task. The simulation of this task fits the requirement for an experimental task in which part-task training variables may be manipulated. In addition to providing a venue for manipulating part-task training variables, the carrier landing task meets Goldstein's (1980) criterion of being organizationally relevant. One of the primary functions of the Navy is the conduct of air operations at sea. In order to maintain a naval air force, pilots must be trained to perform tasks that will allow for successful take-offs and landings aboard aviation-capable ships. Carrier landing is an integral part of this mission. This section contains a description of this task. Included in the discussion are the specific variables to be manipulated in the part-task conditions of this experiment.

During the final approach phase of the carrier landing task, the pilot must perform three tracking tasks simultaneously. These tasks are glideslope tracking, angle of attack tracking, and center line tracking.

The pilot maintains his glideslope position with reference to a visual glideslope indicator located on the carrier deck to the left of the landing area (see Figure 1). This display, called the Fresnel Lens Optical Landing System (FLOLS), consists of two consecutive horizontal bars of five green lights called datum bars and a central light called the ball or meatball. This center light consists of five light beams or cells, only one of which is visible to the pilot at any given time. Presented as Figure 2 is a drawing of the FLOLS assembly. A center ball, consisting of the center light aligned with the datum bars, indicates an on-glideslope condition. Any misalignment of the center light with respect to the datum bars indicates an above- or below-glideslope condition. When an above- or below-glideslope condition exists, corrective action must be taken by the pilot in the form of increased or decreased power, through manipulation of the aircraft's throttles.

Since all carrier landings are flown to engage the tail hook of the aircraft on one of the cables across the landing area, the aircraft must be flown such that a constant angle of attack is maintained throughout the approach. The pilot maintains angle of attack by referring to an instrument called the approach indexer located above the glareshield of the instrument panel. Adjustments to the indexer are effected by forward and backward movements of the aircraft's control stick.

The third feature of carrier final approach tracking is the requirement to line up with the centerline of the landing area. This is accomplished by moving the control stick to the right or left until the nose is pointed at the center line of the landing deck.

Segmentation Variable

The simulator has the flexibility to allow for the division of the carrier landing task into several segments. These segments divided the final approach path into three 2000 foot parts. Specifically, these segments began: 6000 feet from touchdown, 4000 feet from touchdown, and 2000 feet from touchdown. In this way, a part-task training technique of the segmentation type was devised. Since the FLOLS is an angular system, in order for errors to be manifest by movement of the center ball, a displacement of 12 feet is required at 3/4 of a mile while only a one-foot displacement will move the ball close to the ship. Figure 3 illustrates this FLOLS envelope. This means that error tolerances are more stringent closer to the ship than they are further away. The employment of a segmentation strategy which requires practice on the terminal phase of the task initially should lead to better performance upon transfer to the whole task since it should lead to a greater opportunity to practice error corrections, since more errors should be evident. This practice should be more efficient than whole-task practice since it will allow for intensive practice on critical elements of the task.

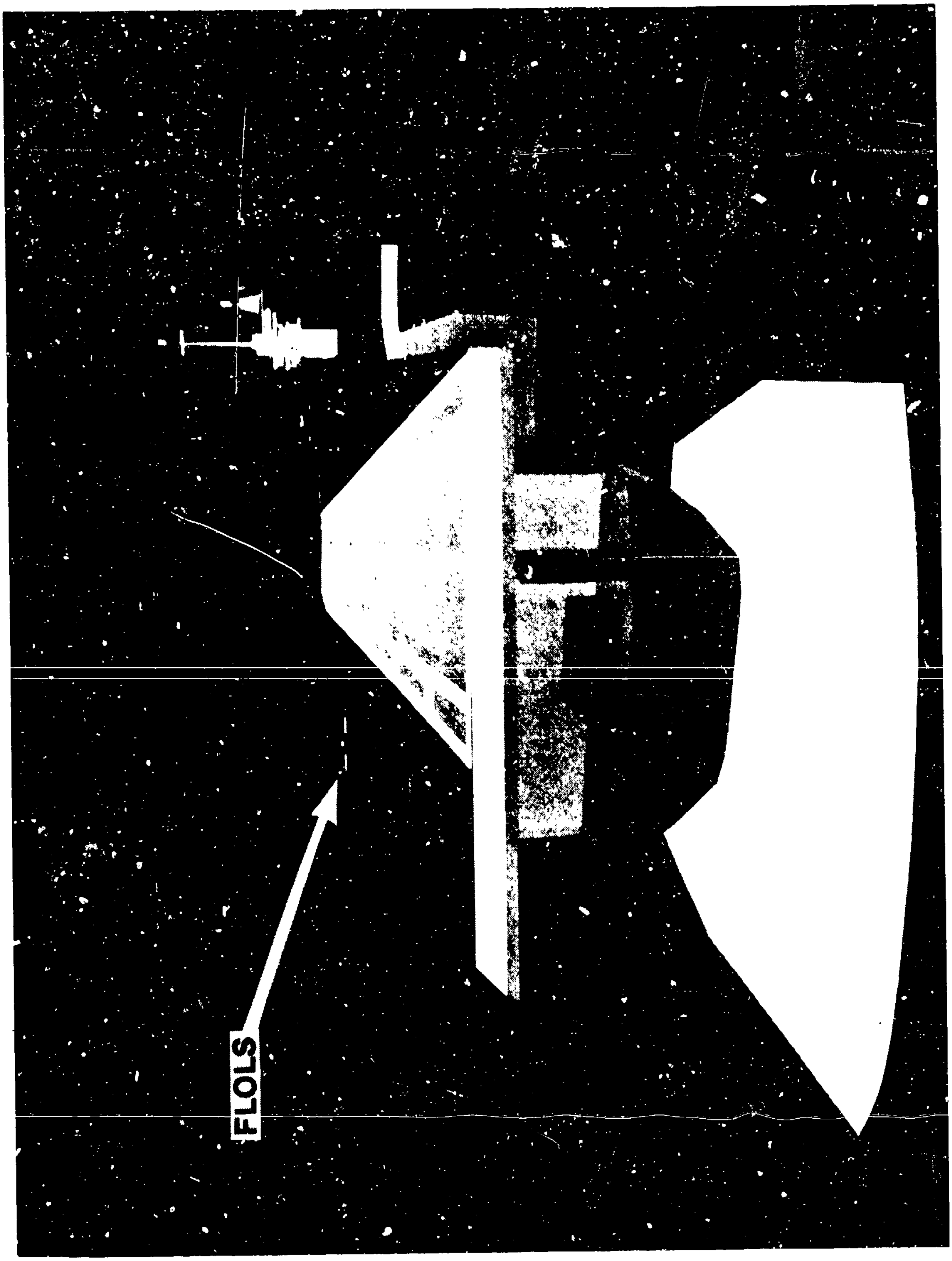

Figure 1. Aircraft Carrier from the Glideslope.
(Note: The Fresnel Lens Optical Landing Systems (FLOLS)

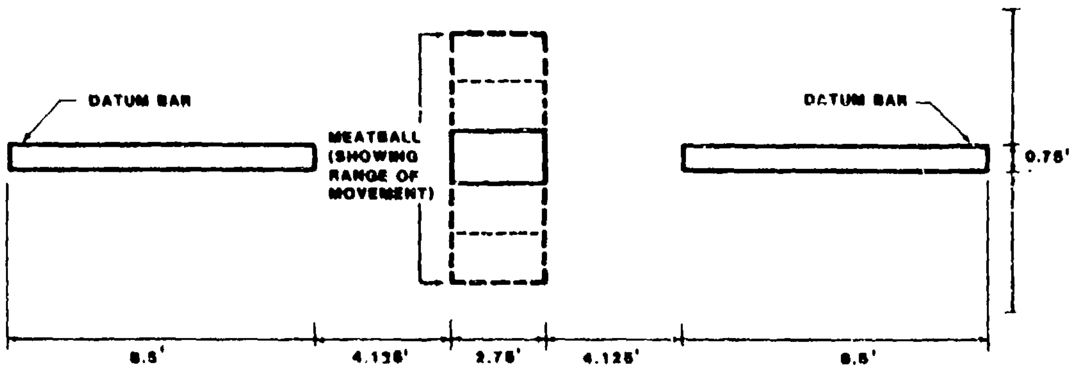

Figure 2. Configuration of FLOLS simulation, showing datum bars and meatball (dimensions shown are in feet).

Simplification Variable

The factor that contributes the most to the difficulty of the carrier glideslope tracking task is the lag that ensues between throttle inputs and changes in the FLOLS ball location. Numerous factors contribute to this state of affairs. Most notable is the engine response time and the aircraft's inertia. This leads to a large requirement being placed upon the novice to lead these system dynamics at the same time as he is trying to acquire information about the nature of corrective inputs in terms of direction, timing, and magnitude. A simplification training technique was employed in this experiment by removing or reducing this lag so that early experience with the throttle-FLOLS tracking relationship gave the information required by the trainee at that point in training. This strategy should only be effective if the trainees are provided with sufficient information about the system lag prior to training and if changes in system lag are prefaced with anticipatory information. Successive approximations to the true system lag should allow for the maximal acquisition of early proficient performance of the carrier glideslope tracking task.

Individual Difference Variable

In addition to creating instructional treatments based upon task manipulations, instructional researchers have been concerned with the large degree of individual differences which exist between subjects within conditions when such instructional treatments are implemented. It has been suggested that measures of subject abilities on the skills in question will contribute to the power of experiments on instructional strategies (Lintern and Kennedy, 1982).

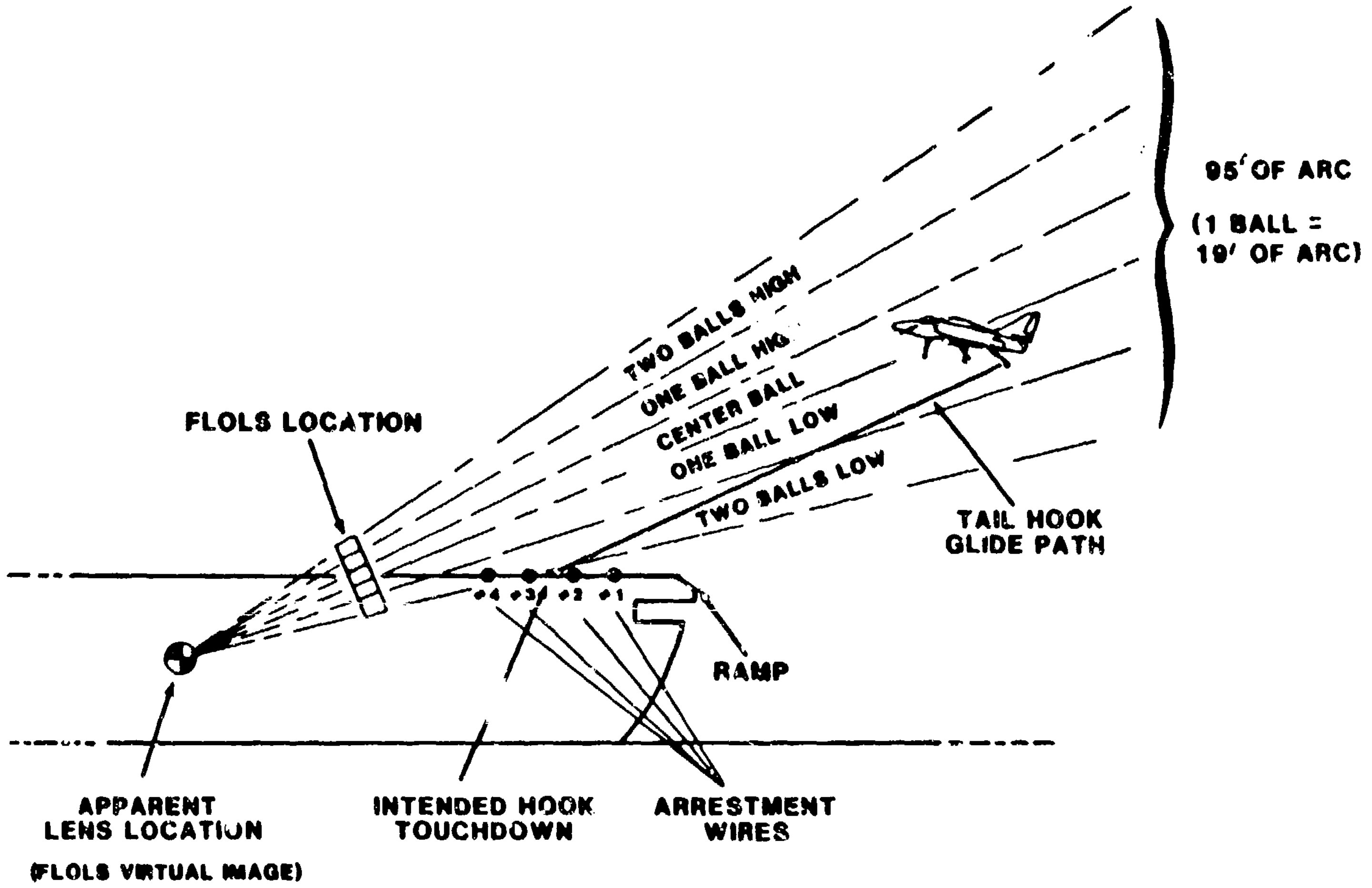

Figure 3. Carrier Approach Schematic Depicting FLOLS Envelope, Tail Hook Glide Path, and Arrestment Wire Locations.

Such measures of individual differences on skills related to tasks being trained can contribute in two ways. First, the control of variability due to initial individual subject differences can increase the precision of the experiment. Secondly, accounting for subject individual differences when assigning subjects to treatment groups allows for the unearthing of possible aptitude by treatment interactions which might go undiscovered if no provision were made for accounting for such differences (Cronbach and Snow, 1977).

One measure that has been found to be of great value in research on human perceptual-motor tasks, is performance on the ATARI Air Combat Maneuvering (ACM) video game (Kennedy, Bittner, and Jones, 1981). This task exhibits good psychometric properties. It has a test-retest reliability of .94 (Kennedy, Bittner, Harbeson, and Jones, 1982) and correlates well with other measure of motor skill. For example, ACM was found to correlate .78 with a compensatory tracking task (Kennedy, Bittner, and Jones, 1981). More recent evidence suggests that this task is particularly well suited to assessing subject skill level for the simulated carrier landing task. Lintern and Kennedy (1982) reported correlations between ACM and the carrier glideslope tracking task in the Visual Technology Research Simulator ranging between .69 and .95 when corrected for attenuation due to the low reliability of the glideslope tracking measure. These data were collected on both military pilots and university students and no differences were observed between the two populations.

Given the potential value of such a measure to improve the power of this experiment and the possibility that such an individual difference factor could unearth an aptitude by treatment interaction, subjects were tested on the ATARI ACM task prior to assignment to experimental conditions. Assignment to experimenal conditions was made such that equal numbers of high and low scorers on the ACM task were placed in each experimental condition.

SECTION II

METHOD

SUBJECTS

Forty subjects participated in this study, with one subject who was ill on the day he performed the transfer task being removed from the experiment leaving a total of 39 subjects for transfer data analysis. These subjects were recruited from undergraduate university students at the University of Central Florida in Orlando, Florida. In order to control for any difference due to sex of subject, only male subjects were used. The subjects ranged in age from 18 to 26 years with a mean age of 21. Subjects were paid $3.00 per hour for participation in the experiment.

APPARATUS

The Visual Technology Research Simulator (VTRS) was the primary apparatus employed in this experiment. The VTRS consists of a fully instrumented T-2C Navy jet trainer cockpit, a six degree-of-freedom synergistic motion platform, a 32-element G-seat, a wide angle visual system that can project both computer-generated and model-board images, and an Experimenter/Operator Control Station (Collyer and Chambers, 1978). The motion system, model-board, and G-seat were not used in this experiment.

Visual System

The background projector of the VTRS projects an image which subtends 50 degrees above to 30 degrees below the pilot's eye level and 80 degrees to either side. The carrier image, a representation of the USS Forrestal (CVA 59), was generated by computer and projected onto the background through a 1025-line video system. A carrier wake and Fresnel Lens Optical Landing system was also generated by this method. Only the daytime scene was used (see Figure 1).

The sky brightness for the daytime scene was 0.85 fL (foot-Lamberts) and the seascape brightness was 0.6 fL. The brightness area of the day carrier was 4.0 fL. Except for the horizon, no features were represented in the sky or sea.

Fresnel Lens Optical Landing System (FLOLS)

In contrast to a carrier FLOLS, which is generated by incandescent light and consequently is brighter than other parts of the aircraft carrier, the simulated FLOLS was generated by the same system as the carrier image. Because of this, the FLOLS was only as bright as the brightest areas of the ship. To compensate for this lower relative brightness, the FLOLS was enlarged by a factor of 4.5 when the distance from the carrier was greater than 2250 feet. From 2250 feet the size of the FLOLS was linearly reduced until it attained 1.5 times normal size at 750 feet. It remained this size throughout the remainder of the approach.

Simulator Configuration

The simulated T-2C was initialized in the approach configuration for carrier landings (full flaps, hook and wheels down, speed-brake out, 15 units angle-of-attack, and 83% power) for all conditions.

The carrier day scene was the image presented in all of the conditions. The carrier was set on a heading of 360 degrees at 5 knots. Environmental wind was set at 349.5 degrees with a velocity of 20.1 knots. This combination of carrier speed and environmental wind produced a relative wind component of 25 knots down the landing deck.

TRAINING CONDITIONS

Four training conditions were employed in this experiment: whole task with normal lag, whole task with progressively increased lag, segmented task with normal lag, and segmented task with progressively increased lag.

Whole Task With Normal Lag

Subjects practiced the carrier landing task as it is normally presented in the simulator, with the normal delay between the throttle input and movement of the meatball part of the FLOLS. Each trial consisted of attempting a carrier landing from 6000 feet to touchdown on the deck. These subjects were given 48 trials of training in three blocks of 16 trials.

Whole Task With Progressively Increased Lag

Subjects were trained on the carrier landing task in the same manner as in the whole task-normal lag condition, beginning each trial from 6000 feet. However, these subjects were given the first 16 trials under a reduced lag condition, the second 16 trials under a lag less than the normal lag, and the last 16 trials under a lag equal to the normal lag. Prior to the changes in lag, each subject was given information to alert him to the fact that a change in lag was to be expected in the system and to anticipate this lag when applying error corrections.

Since the inertia of the aircraft contributes the most to the lag which ensues between throttle inputs and aircraft response and since inertia is largely a function of the mass of the aircraft, the simulated T-2C's weight was modified by changing the fuel quantity in order to implement the progressive lag manipulation. For the lowest lag condition, the aircraft was loaded with 225 pounds of fuel, for the intermediate lag condition 2225 pounds of fuel was loaded, and for the longest lag condition 4225 pounds of fuel were loaded. Preliminary testing with experienced pilots indicated that these weights led to significant and discriminably differt change in the responsiveness of the aircraft over the range of fuel quantities. These pilots stated that the 225 pound level resulted in a very responsive aircraft with very little delay between throttle inputs and position changes while the 2225 pound load resulted in a more sluggish but still responsive aircraft, and the 4225 pound loaded T-2 was quite sluggish.

Segmented With Normal Lag

Subjects performed segments of the carrier landing task beginning at 2000 feet from touchdown for 16 trials, then beginning at 4000 feet from touchdown for 16 trials, and finally beginning at 6000 feet from touchdown for 16 trials. All trials were flown with the normal lag for the carrier landing task.

Segmented With Progressively Increased Lag

Subjects performed as in the segmented normal lag condition except that, within each segment, lag was varied. This resulted in a training program such that the first 16 trials were flown from 2000 feet to touchdown with minimal lag between throttle inputs and meatball movement; the second 16 trials were flown from 4000 feet to touchdown at a lag equal to approximately one-half the normal lag; and the last 16 trials were flown from 6000 feet to touchdown at the lag normally experienced with the carrier landing system. As in the whole task with progressively increased lag, each subject was provided with information about the nature of lag as l g was imposed.

Motor Skill Level

The ATARI video game console with the Air Combat Maneuvering (ACM) tape (CX-2601-24) inserted was used to gather data on subject motor-skill ability. All presentations were on a black and white television screen situated 1.4m from the subject. The task consisted of an attack jet and a target drone presented on the screen. The subject's task was to shoot down as many target drones as possible in the time allowed. The score was the absolute number of hits per game. High scorers were defined as subjects whose scores were above the 50th percentile on the mean of the last 10 trials of the ATARI ACM video game, low scorers were defined as subjects whose scores were below the 50th percentile on the mean of the last 10 trials.

PROCEDURE

The experimental procedure consisted typically of four separate sessions which required each subject to come to the simulator facility on at least three separate occasions.

Session I: Motor Skill Data Collection

On the first scheduled session each subject performed the ATARI Air Combat Maneuvering Videogame as described above. The subject read the following instructions:

> The object of the Air Combat Maneuvering Test is to hit the white target "jet fighter" as many times as possible with the missile from the black "jet fighter." Hold the joystick with the red button to your upper left towards the TV screen. The speed of your "jet" is controlled by moving your joystick forward for the fastest movement and back toward you for the slowest movement. Right and left turns are made by pushing the joystick to the right and left, respectively. Fire

your missile by pushing the red button on your controller. One point will be scored for each time you hit the white target with the missile from your black "jet." At the end of two minutes and 16 seconds the task will automatically end and your final score will be displayed at the top of the screen. You will be given ten trials per block and three blocks. Any questions?

After reading the instructions, the subject performed the videogame and recorded his score for each game on a score sheet provided. Spot checks were made by the experimenter during the testing session to verify the accuracy of the subject score. After completing 30 trials of the game, the subject was given a date and time to reappear for the instructional session, the simulator training session and the simulator testing session. Subjects, stratified by motor skill, were randomly assigned to the training conditions.

Session II: Carrier Landing Instructional Session

Upon arrival at the simulator facility, the subject was requested to read an instructional booklet which explained the essential element of carrier landings[1]. After reading these instructions the subject was given a brief lecture highlighting the main points of the carrier landing instructional booklet. This lecture was delivered by the experimenter who served as the instructor throughout the experiment. During and after the lecture, the subject was allowed to ask any questions he wished pertaining to the carrier landing task and the technique required to perform it. In most cases simulator training immediately followed the instructional session. In the event simulator training did not follow the instructional session immediately, the subject was allowed to reread the instructional booklet and a refresher lecture was provided just prior to the training.

Session III: Simulator Training

The simulator training session began with the subject reading the instructions specific to his particular training condition. These special instructions are provided in Appendix A. Once the subject had read and understood the special instructions, he was placed in the simulator cockpit. He was then given a briefing on the location of the instruments, controls, and displays described in the instructional booklet.

Once the subject was ready to begin, he was given the opportunity to fly two familiarization flights. These flights consisted of two attempts to land on the aircraft carrier in the testing condition (from 6000 feet and with the maximum throttle lag). No data were recorded for the familiarization trials. Once these trials were completed, the training session began. Following each training trial the instructor provided feedback to the subject concerning performance and gave suggestions for corrective technique.

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[1] This instructional booklet is available from the author upon request.

Training trials were conducted in three blocks of 16 trials each. Between each trial block, the subject was given a rest break of at least ten minutes during which time he was required to leave the simulator cockpit and wait in an adjoining room.

Session IV: Simulator Testing

Each subject was asked to return on the day following Session III in order to participate in the Simulator Testing Session. All of the subjects were able to comply with this request with one exception. The subject who was unable to return on the day following Session III returned on the second day following Session III to participate in the simulator testing session.

Session IV consisted of two trial blocks of 18 and 14 trials respectively for a total of 32 trials. The testing trials were the same as the whole task, normal lag condition (i.e. the carrier approach from 6000 feet behind the carrier with the most sluggish throttle response). The subject was placed in the simulator cockpit and was read the following instructions:

> Today we will test your performance on the carrier landing task you were trained to do. These landings will be just like the ones you did yesterday except I will not be giving you any instructional feedback following your landings. Before we do the testing session, I will allow you to perform two warm-up trials. Following each of these warm-up trials, I will give you brief feedback concerning your performance; after that the testing session begins and I won't talk to you following a landing except to tell you which wire you caught when you make a landing.

At the end of the first 18 trials, the subject was given a rest period of ten minutes outside the simulator cockpit. Following the second trial block of testing trials, the subject was released.

SECTION III

RESULTS

In order to address the major hypotheses about the effects of segmentation, lag, and motor skill on performance of the carrier landing final approach task, analyses of variance were carried out on both the training and transfer data. The analyses of variance took the form of a mixed design with the three independent variables as between-subjects factors and trial blocks as a repeated or within-subjects factor. The carrier landing performance was measured in three dependent measures: the root mean square (RMS) error for the glideslope in degrees, line-up in feet, and angle of attack in units. RMS glideslope angle error was considered to be the most important dependent variable because it most closely captured the primary focus of the subject in the carrier landing task.

The distributions and variances of the data in raw form violated the assumptions of the analysis of variance. In order to meet the normal distribution and homogeneity of variances requirements, the data were transformed by means of a logarithmic transformation (Winer, 1971) taking the form of $X' = \log (X+1)$. Subsequent analyses were performed on the transformed data. An alpha level of $p < .05$ was selected for determination of statistical significance for the ANOVA tests as well as for the Newman-Keuls tests (Winer, 1971) used for the multiple comparisons among the means of significant effects.

TRAINING DATA ANALYSIS

Since the training task manipulation yielded glideslope approaches of differing lengths, under different conditions (e.g., a subject in the segmentation task condition would begin from 2000 feet in his first trial whereas a whole task subject would begin at 6000 feet), analyses of variance were conducted for the three performance measures in training over the last 1000 feet of the approach. These analyses took the form of 2x2x2x6 analyses of variance with repeated measures of the within subjects factor of trial blocks. A trial block, for training trials, consisted of the average score for eight training trials.

RMS Glideslope Angle Error

Table 1 is the summary table for the analysis of variance conducted on the dependent variable of RMS glideslope angle error. Significant main effects were revealed for the between-subjects factors of task ($F=5.87$, $p < .05$) and motor skill ($F=6.38$, $p < .05$). An examination of means for these between-subjects effects (Table 2) shows that the task effect was due to lower error scores during training on the part of the subjects trained in the segmented task condition. The motor skill effect was due to lower average errors being made by the subjects in the high motor skill category throughout the course of training.

TABLE 1
ANALYSIS OF VARIANCE FOR RMS
GLIDESLOPE ANGLE FOR TRAINING DATA

SOURCE	df	MS	F
Between Subjects			
Task (T)	1	.279	5.87**
Lag (L)	1	.0035	< 1
Motor Skill (M)	1	.303	6.38**
TXL	1	.023	< 1
TXM	1	.0008	< 1
LXM	1	.030	< 1
TXLXM	1	.0004	< 1
Error	31	.0475	
Within Subjects			
Blocks (B)	5	.023	2.80**
BXT	5	.093	11.38*
BXL	5	.012	1.41
BXM	5	.010	1.27
BXTXL	5	.022	2.68*
BXTXM	5	.015	1.77
BXLXM	5	.007	< 1
Error	155	.0082	

*p < .01
**p < .05

TABLE 2
MEANS OF RMS GLIDESLOPE ANGLE FOR
TRAINING TRIAL BLOCKS BY GROUP

GROUP	TRIAL BLOCKS						
	1	2	3	4	5	6	MEAN
				Task			
Whole							
Raw Score	2.89	2.27	1.45	1.26	1.36	1.34	1.76
Log (X+1)	.47	.39	.33	.31	.33	.32	.36
Segmented							
Raw Score	.84	.76	2.02	1.29	1.33	.96	1.20
Log (X+1)	.24	.23	.36	.30	.32	.27	.29
				Lag			
Normal							
Raw Score	1.95	1.76	1.32	1.14	1.36	1.14	1.44
Log (X+1)	.36	.34	.32	.29	.33	.29	.32
Progressive							
Raw Score	1.85	1.32	2.12	1.40	1.34	1.17	1.53
Log (X+1)	.35	.28	.37	.32	.33	.31	.33
				Motor Skill			
High							
Raw Score	1.44	.93	1.05	1.03	1.22	1.04	1.12
Log (X+1)	.32	.26	.29	.28	.31	.28	.29
Low							
Raw Score	2.38	2.17	2.44	1.53	1.49	1.28	1.88
Log (X+1)	.40	.37	.41	.33	.35	.32	.36
				Blocks			
Raw Score	1.89	1.53	1.73	1.27	1.35	1.16	
Log (X+1)	.36	.31	.35	.30	.33	.30	

	Grand Mean	Standard Deviation
Raw Score	1.49	1.46
Log (X+1)	.33	.14

A significant effect was also shown by the within-subjects factor of blocks ($F=2.80$, $p < .05$), indicating that a significant change took place over training trials. In order to clarify the nature of the statistically significant difference across blocks, the Newman-Keuls test (Winer, 1971) was used to compare the means. This test showed that the significant difference of blocks was due to the mean glideslope performance on blocks one and three being significantly different from the mean glideslope performance on blocks two, four, and six. Performance on blocks one, three, and five did not differ from one another nor did the means of blocks two, four, five and six differ. Figure 4 is a graph of the RMS glideslope angle error scores plotted against trial blocks. This graph shows a downward trend for this measure across blocks.

Table 1 also indicates a significant interaction between trial blocks and task type ($F=11.38$, $p < .01$). Figure 5 is a graph of this interaction. The Newman-Keuls test showed that this interaction effect was due to the superiority of the segmented training strategy on blocks one, two, and six. There were no significant differences between the two task manipulations on any of the other blocks of training trials.

Fina , Table 1 shows a significant three-way interaction of the task, lag, and blocks factors ($F=2.68$, $p < .05$). The means for this interaction are presented in Table 3 and a graph of this interaction is presented as Figure 6. The Newman-Keuls test among the mean differences was carried out for each of the task-lag pairings within blocks. On block one, a superiority was shown for the segmented conditions with the segmented groups significantly better than the whole groups. On block two, this trend continued, but the two whole task conditions were significantly different from one another. The whole task - progressive lag condition was superior to the whole task - normal lag condition. The two segmented conditions were identical and significantly better than both of the whole task conditions. On block three the order of the groups changed such that the two whole task groups continued their downward trend while the segmented groups showed an upward trend. The test for mean differences for block three showed no difference between the whole task groups and the segmented task - normal lag group while the segmented task - progressive lag group was significantly worse than the other three. On block four, the order was basically the same as block three except that the statistically significant difference was in the difference between the two extreme groups of segmented task - normal lag and segmented task - progressive lag, with the segmented task - normal lag condition superior on this block. On block five the whole task - normal lag and segmented task - progressive lag conditions were not significantly different from one another but were significantly superior to the whole task - normal lag and segmented task - normal lag conditions, while these latter two groups were not significantly different from each other. On block six, the segmented task groups were not significantly different from each other but both were significantly superior to the whole task - progressive lag condition. The whole task conditions were not significantly different from one another on block six, but both were significantly different from the segmented task - normal lag condition which was the superior training condition.

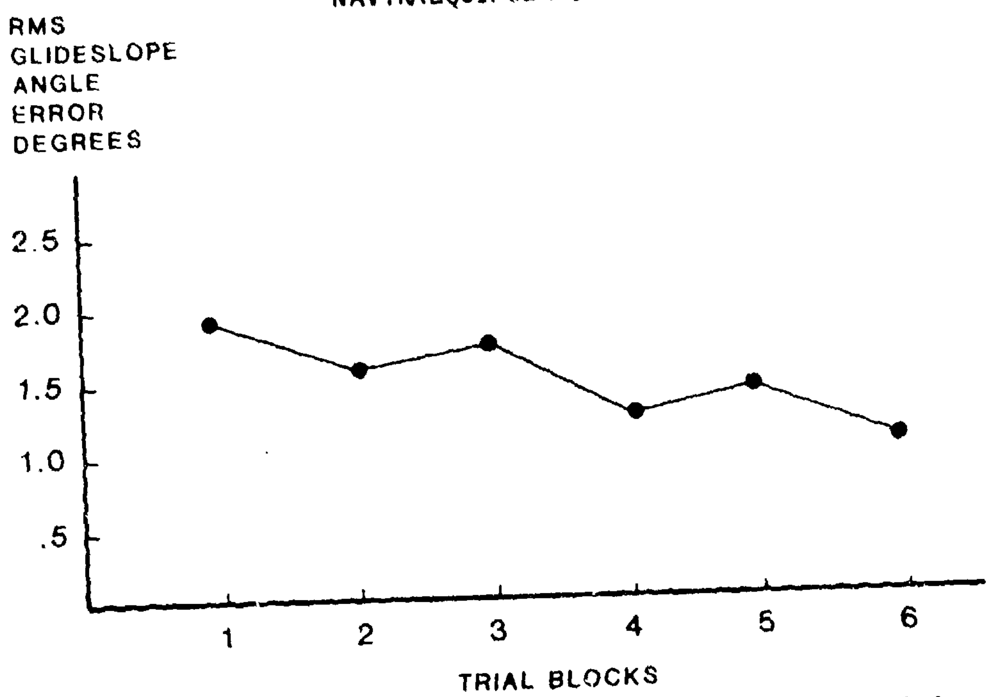

Figure 4. RMS Glideslope Angle Error by Trail Blocks for Training Trials.

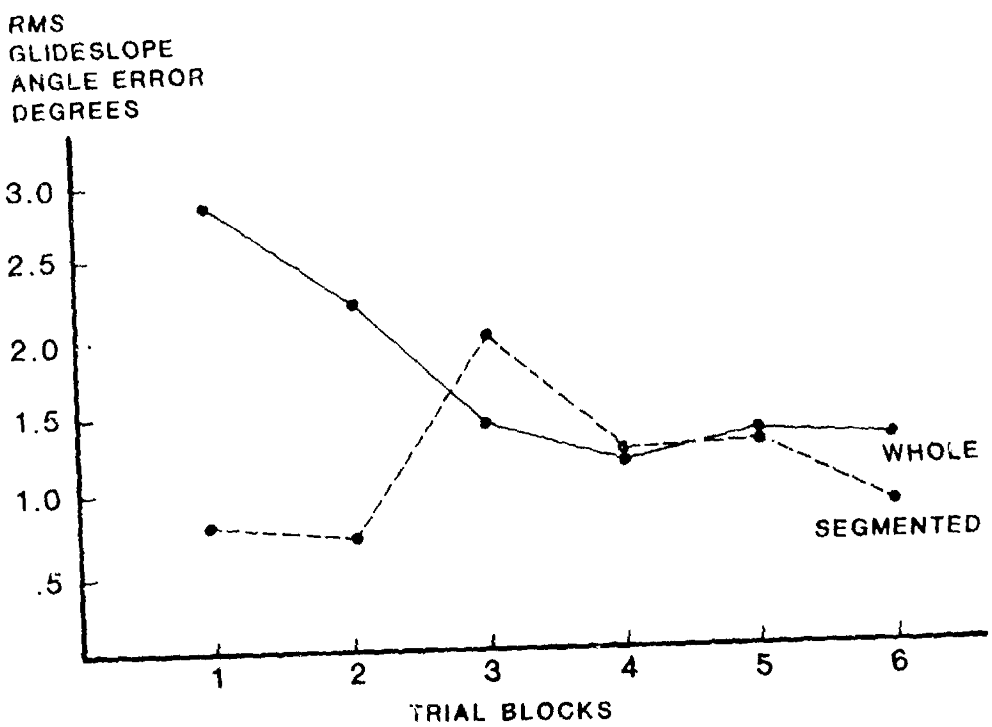

Figure 5. Task by Blocks Interaction for RMS Glideslope Angle on Training Trials.

TABLE 3
MEAN OF BLOCK BY TASK BY LAG INTERACTION
FOR RMS GLIDESLOPE ANGLE FOR TRAINING DATA

GROUP	TRIAL BLOCKS 1	2	3	4	5	6	MEAN
Whole Task Normal Lag							
Raw Score	2.95	2.68	1.41	1.24	1.19	1.38	1.81
Log (X+1)	.47	.44	.35	.31	.31	.32	.37
Whole Task Progressive Lag							
Raw Score	2.84	1.86	1.49	1.27	1.54	1.30	1.72
Log (X+1)	.46	.34	.31	.31	.36	.33	.35
Segmented Task Normal Lag							
Raw Score	.83	.74	1.21	1.02	1.54	.87	1.03
Log (X+1)	.25	.23	.29	.27	.35	.26	.27
Segmented Task Progressive Lag							
Raw Score	.85	.78	2.74	1.53	1.14	1.04	1.35
Log (X+1)	.24	.23	.43	.33	.30	.28	.30

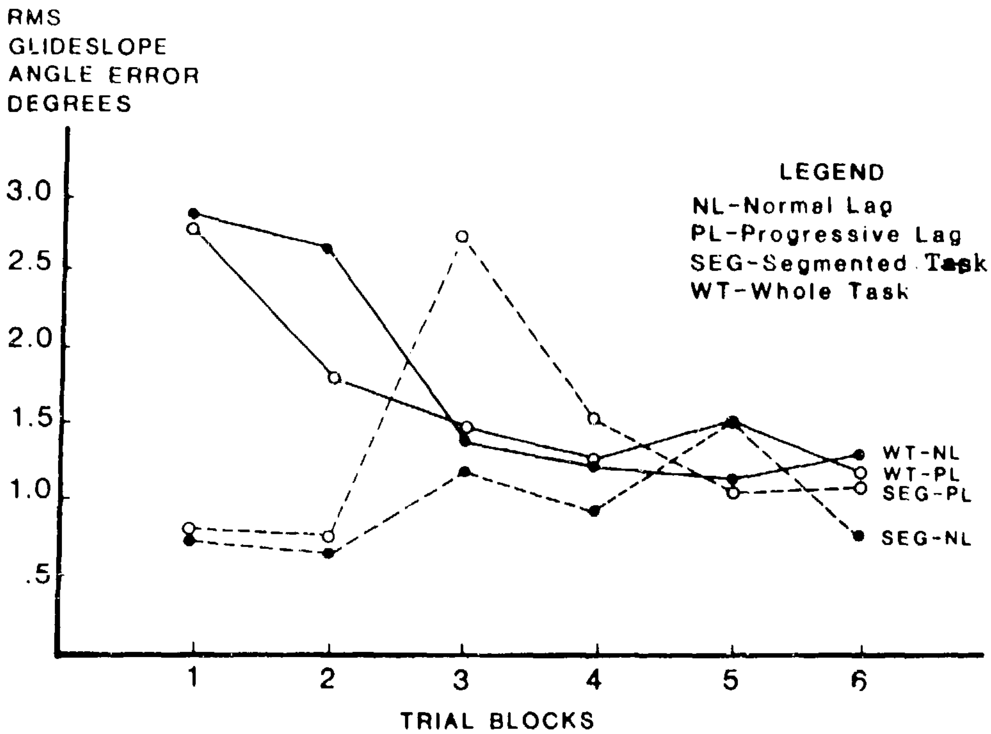

Figure 6. Graph of Blocks by Task by Lag Interaction for RMS Glideslope Angle Training Trials.

RMS Line-Up Error

Table 4 is the summary table for the analysis of variance conducted on the dependent variable of RMS line-up in feet. This measure indicates how much the subject's performance deviated from a desired path that describes the center line of the landing area. A significant main effect was found for the between-subjects factor of motor skill ($F=8.37$, $p < .01$) and for the within-subjects factor of blocks ($F=4.96$, $p < .01$). A significant two-way interaction was revealed for the blocks by task combination ($F=10.41$, $p < .05$).

Table 5 contains the means for the RMS line-up scores for the training trial blocks. Inspection of Table 5 shows that the significant main effect for motor skill was due to the high motor skill group subjects performing better on line-up than the low motor skill group.

The Newman-Keuls test showed that the blocks effect was due to a statistically significant difference between trial blocks one versus three, four, and five. Block two showed a statistically reliable difference from blocks three and four, but was not statistically different from block five. Block six was not significantly different from any of the other blocks. Figure 7 is a graph of the RMS line-up error scores across trial blocks.

An examination of the task by trial blocks interaction by comparing mean differences within blocks with the Newman-Keuls procedure indicated that a significant difference existed between segmented and whole task type groups on trial blocks one, two, three, and six while these two groups did not differ on

TABLE 4
ANALYSIS OF VARIANCE SUMMARY TABLE FOR
LOG OF RMS LINE-UP FOR TRAINING DATA

SOURCE	df	MS	F
Between Subjects			
Task (T)	1	.449	3.54*
Lag (L)	1	.111	< 1
Motor Skill (M)	1	1.064	8.37***
TXL	1	.220	1.73
TXM	1	.003	< 1
LXM	1	.059	< 1
TXLXM	1	.002	< 1
Error	31	.127	
Within Subjects			
Blocks (B)	5	.116	4.96***
BXT	5	.245	10.41***
BXL	5	.031	1.33
BXM	5	.013	< 1
BXTXL	5	.015	< 1
BXTXM	5	.032	1.36
BXLXM	5	.026	1.12
BXTXLXM	5	.018	< 1
Error	155	.0239	

*p < .10
**p < .05
***p < .01

TABLE 5
MEANS OF RMS LINE-UP FOR
TRAINING TRAIL BLOCKS BY GROUP

GROUP	TRIAL BLOCKS 1	2	3	4	5	6	MEAN
				Task			
Whole							
Raw Score	48.61	33.43	23.80	25.00	25.87	27.30	30.67
Log (X+1)	1.37	1.34	1.29	1.31	1.32	1.31	1.32
Segmented							
Raw Score	14.42	13.72	33.09	29.20	25.40	21.30	22.85
Log (X+1)	1.09	1.07	1.39	1.35	1.30	1.23	1.24
				Lag			
Normal							
Raw Score	36.49	22.93	23.71	24.40	21.17	20.36	24.80
Log (X+1)	1.25	1.20	1.32	1.32	1.24	1.23	1.26
Progressive							
Raw Score	27.64	24.68	32.71	29.55	29.89	28.19	28.78
Log (X+1)	1.23	1.21	1.36	1.34	1.38	1.31	1.30
				Motor Skill			
High							
Raw Score	18.31	15.74	20.86	21.80	21.85	20.23	17.23
Log (X+1)	1.15	1.12	1.25	1.27	1.27	1.22	1.21
Low							
Raw Score	46.32	32.34	36.18	32.56	29.63	28.73	34.29
Log (X+1)	1.33	1.29	1.43	1.40	1.36	1.32	1.36
				Blocks			
Raw Score	31.95	23.83	28.32	27.04	25.64	24.38	
Log (X+1)	1.24	1.21	1.34	1.33	1.31	1.27	

	Grand Mean	Standard Deviation
Raw Score	26.86	26.43
Log (X+1)	1.29	.23

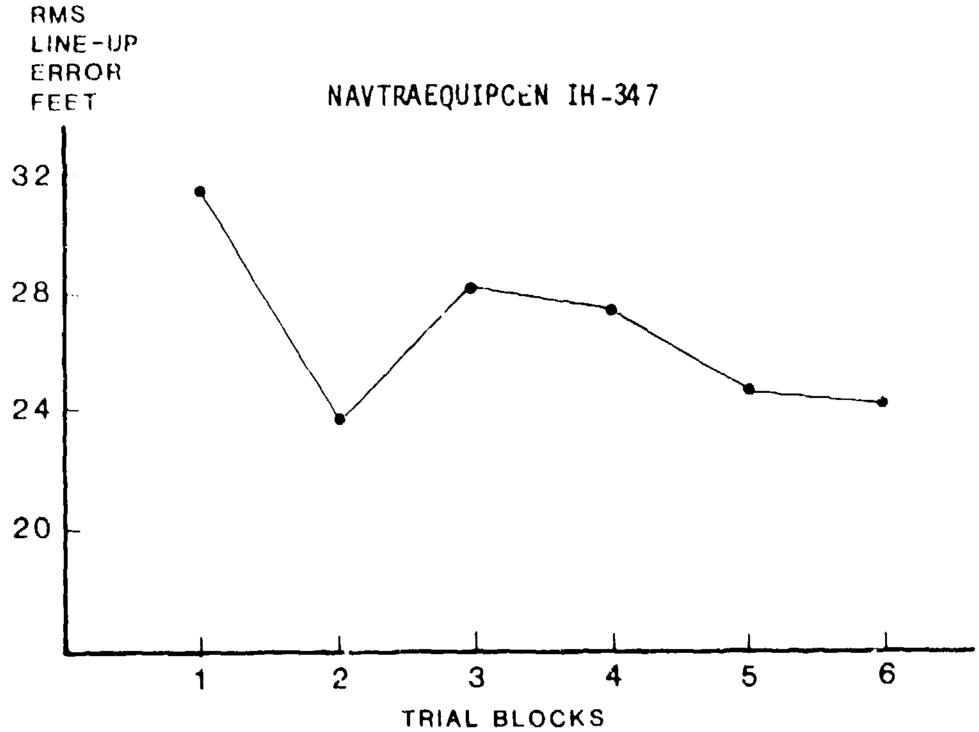

Figure 7. Graph of RMS Line-Up Error by Blocks for Training Trials.

blocks four and five. On trial blocks one, two, and six, the segmented task group was superior to the whole task group while the opposite was true on trial block three. Figure 8 illustrates this interaction.

RMS Angle of Attack Error

An analysis similar to the previous two was carried out on the dependent variable of RMS angle of attack error. Table 6 summarizes this analysis. Significant main effects were found for the between-subjects factor of motor skill ($F=5.13$, $p < .05$) and for the within-subjects factor of blocks ($F=3.36$, $p < .05$). The motor skill main effect was due to higher motor skill subjects maintaining a lower RMS angle of attack error throughout training than the low motor skill group as shown in Table 7.

To determine the nature of the blocks effect, the Newman-Keuls test of mean comparisons was carried out. The comparison showed the main effect of blocks to be due to the significant difference between block one versus blocks four, five, and six. A graph of the mean RMS angle of attack error scores across trial blocks is presented as Figure 9.

TRANSFER DATA ANALYSIS

The crucial test of any training manipulation lies in the effects that are observed when subjects are required to perform the task in the testing or transfer situation. The analysis of the transfer data took the form of two sets of analysis of variance. One set was performed on the subjects' transfer performance across the whole 6000 feet of the approach, since all of the subjects performed this task as their testing or transfer task. In addition, a set of analyses was conducted for the last 1000 feet of the approach. These analyses were carried out to investigate differences on the terminal phase of task performance. The analyses carried out on the transfer data had the same

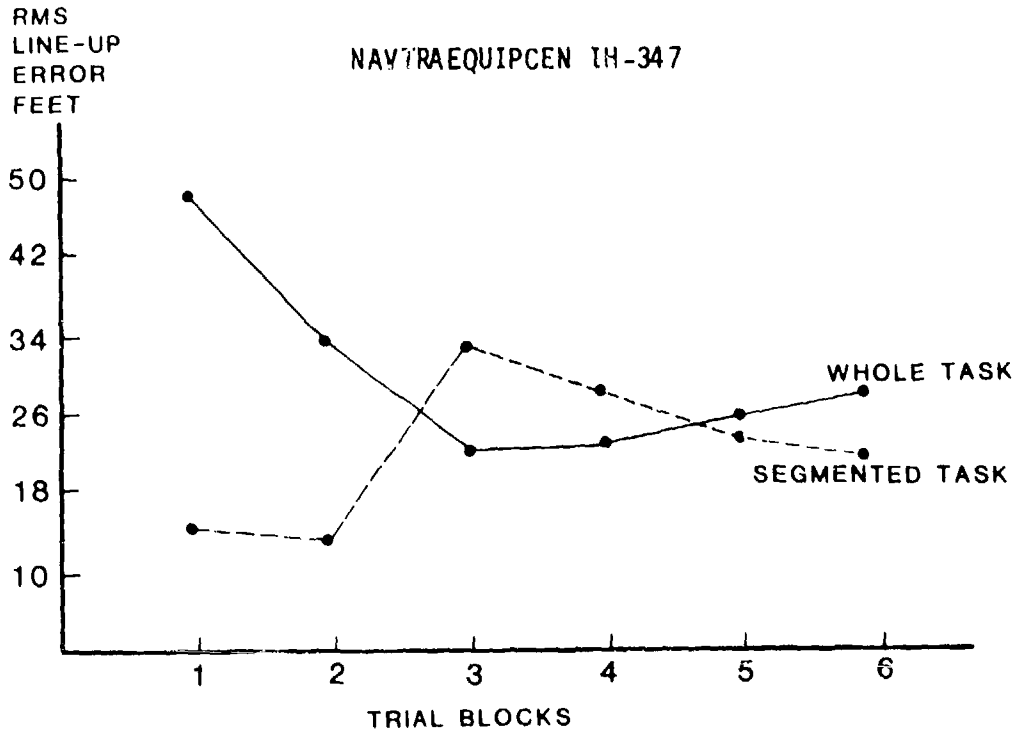

Figure 8. Graph of Tasks by Blocks Interaction for RMS Line-Up Error for Training Trials.

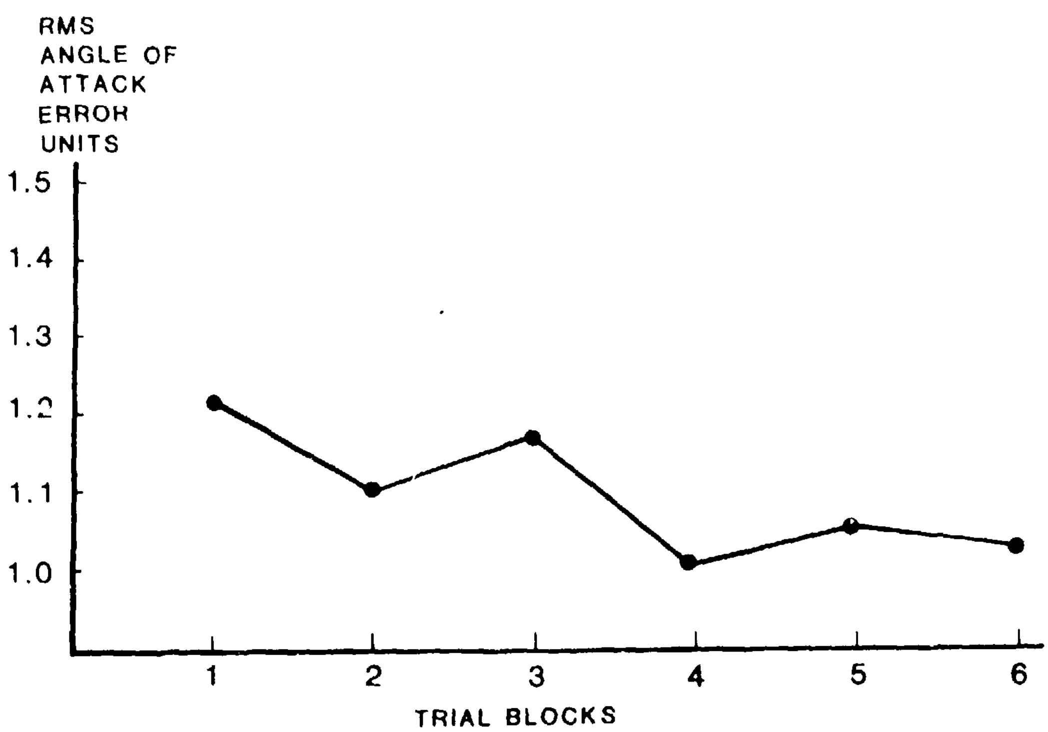

Figure 9. Graph of RMS Angle of Attack Error for Training Trial Blocks.

TABLE 6
ANALYSIS OF VARIANCE SUMMARY TABLE FOR LOG OF RMS ANGLE OF ATTACK FOR TRAINING DATA

SOURCE	df	MS	F
Between Subjects			
Task (T)	1	.0354	2.25
Lag (L)	1	.0577	3.67*
Motor Skill (M)	1	.0809	5.13**
TXL	1	.0305	1.94
TXM	1	.0191	1.22
LXM	1	.2000	1.27
TXLXM	1	.00648	< 1
Error	31	.01575	
Within Subjects			
Blocks (B)	5	.0126	3.36**
BXT	5	.00710	1.89
BXL	5	.0045	1.21
BXM	5	.0016	< 1
BXTXL	5	.0019	< 1
BXTXM	5	.0022	< 1
BXLXM	5	.0053	1.43
BXTXLXM	5	.0017	< 1
Error	155	.0037	

*p < .10
**p < .05

TABLE 7
MEANS OF RMS ANGLE OF ATTACK
FOR TRAINING TRIAL BY GROUP

GROUP	TRIAL BLOCKS 1	2	3	4	5	6	MEAN
				Task			
Whole							
Raw Score	1.37	1.16	1.06	.94	.92	.93	1.06
Log (X+1)	.33	.31	.29	.27	.26	.26	.29
Segmented							
Raw Score	1.17	1.05	1.31	1.06	1.17	1.14	1.15
Log (X+1)	.32	.30	.34	.30	.31	.30	.31
				Lag			
Normal							
Raw Score	1.34	1.13	1.18	1.09	1.20	1.10	1.17
Log (X+1)	.34	.31	.32	.30	.32	.30	.32
Progressive							
Raw Score	1.20	1.08	1.18	.91	.89	.97	1.04
Log (X+1)	.32	.30	.31	.27	.25	.26	.29
				Motor Skill			
High							
Raw Score	1.17	.97	1.01	.94	.98	.92	1.00
Log (X+1)	.31	.28	.29	2.7	.28	.26	.28
Low							
Raw Score	1.37	1.25	1.36	1.05	1.10	1.15	1.21
Log (X+1)	.36	.36	.33	.29	.28	.29	.32
				Blocks			
Raw Score	1.27	1.11	1.18	1.00	1.04	1.03	
Log (X+1)	.33	.31	.31	.29	.29	.28	

	Grand Mean	Standard Deviation
Raw Score	1.11	.44
Log (X+1)	.30	.08

general form as those performed on the training data: 2x2x2x4 analyses of variance with repeated measures on the within-subjects factor of trial blocks for the first four trial blocks of transfer. The transfer blocks consisted of the four trial means for blocks two, three, and four while block one was comprised of the means of the first two transfer trials.

RMS Glideslope Angle Error - 6000 Foot Approach

The analysis summary table for the dependent variable of glideslope angle error for the 6000 foot approach is presented in Table 8. Significant main effects were found for task ($F=6.70$, $p < .05$) and motor skill ($F=5.72$, $p < .05$). An inspection of the means for these two main effects (Table 9) shows that the task effect was due to the subjects in the segmentation condition performing significantly better on the transfer task than the subjects trained with the whole task. Table 9 shows that the subjects in the high motor skill category performed significantly better on transfer than did their counterparts in the low motor skill group. This motor skill main effect was moderated by a significant two-way interaction between lag and motor skill ($F=4.65$, $p < .05$). The means for the cells involved in this interaction are presented in Table 10. A representation of this interaction is presented in Figure 10. The statistical analysis between group means revealed that the difference between lag categories for the high motor skill groups was not statistically significant while the difference between these groups for the low motor skill subjects was ($F=4.46$, $p < .05$). This indicates that the low skill subjects trained under the progressive lag technique performed significantly more poorly on the transfer task than those trained with the normal lag.

In addition to the between-subjects effects, significant effects were found for the within-subjects factor of blocks ($F=4.78$, $p < .01$) and the three-way interaction of blocks by task by lag ($F=4.70$, $p < .01$). The Newman-Keuls test of mean differences showed that the blocks effect was due to the difference between performance on trial block one and the other three trial blocks. Performance on block one exhibited significantly greater error than the transfer performance on the other three. Additionally, block three was found to be significantly different from blocks one, two, and four with performance on block three being superior to performance on the other three blocks. Performance on blocks two and four did not differ. Figure 11 is a graph of the RMS glideslope angle error by trial blocks.

The significant interaction between trial blocks and task and lag manipulations suggests that the transfer performance across blocks exhibited differing trends dependent upon which task - lag group combination was considered. The means of these groups are presented in Table 11. Figure 12 shows these trend differences across trial blocks for the different combinations of training conditions. The Newman-Keuls test indicated that a significant difference existed between segmented task - normal lag and all

TABLE 8
ANALYSIS OF VARIANCE SUMMARY TABLE
FOR LOG OF RMS GLIDESLOPE ANGLE FOR
TRANSFER DATA 6000 FEET TO THE RAMP

SOURCE	df	MS	F
Between Subjects			
Task (T)	1	.0737	6.70**
Lag (L)	1	.0122	1.11
Motor Skill (M)	1	.0629	5.72**
TXL	1	.0041	< 1
TXM	1	.0066	< 1
LXM	1	.0511	4.65**
TXLXM	1	.0012	< 1
Error	31	.0110	
Within Subjects			
Blocks (B)	3	.0136	4.78*
BXT	3	.0013	< 1
BXL	3	.0005	< 1
BXM	3	.0029	1.04
BXTXL	3	.0134	4.70*
BXTXM	3	.0049	1.73
BXLXM	3	.0028	< 1
BXTXLXM	3	.0047	1.66
Error	93	.0028	

*$p < .01$
**$p < .05$

TABLE 9
MEANS OF RMS GLIDESLOPE ANGLE FOR TRANSFER TRIAL BLOCKS BY GROUP 6000 FEET TO THE RAMP

GROUP	TRIAL BLOCKS 1	2	3	4	MEAN
Task					
Whole					
Raw Score	.79	.72	.64	.65	.70
Log (X+1)	.25	.23	.20	.22	.22
Segmented					
Raw Score	.69	.54	.51	.47	.55
Log (X+1)	.21	.18	.17	.16	.18
Lag					
Normal					
Raw Score	.71	.61	.53	.54	.53
Log (X+1)	.23	.20	.17	.18	.21
Progressive					
Raw Score	.78	.66	.63	.58	.58
Log (X+1)	.23	.22	.20	.19	.24
Motor Skill					
High					
Raw Score	.64	.57	.50	.45	.54
Log (X+1)	.21	.19	.17	.16	.17
Low					
Raw Score	.85	.70	.66	.68	.72
Log (X+1)	.25	.22	.21	.22	.22
Blocks					
Raw Score	.70	.54	.51	.47	
Log (X+1)	.25	.23	.20	.22	

	Grand Mean	Standard Deviation
Raw Score	.63	.32
Log (X+1)	.20	.08

TABLE 10
MEANS OF RMS GLIDESLOPE ANGLE FOR
TRANSFER BLOCKS FOR MOTOR SKILL
BY LAG 6000 FEET TO THE RAMP

	MOTOR SKILL	
	HIGH	LOW
Lag		
Normal	.59	.61
(Transformed)	.19	.20
Progressive	.50	.82
(Transformed)	.17	.25

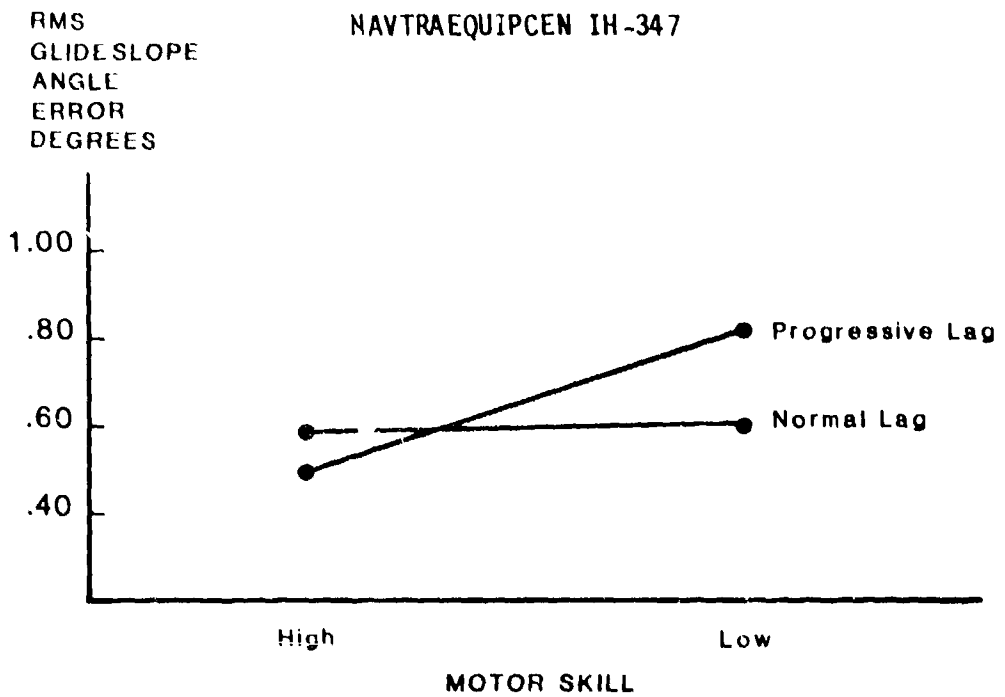

Figure 10. Graph of the Lag by Motor Skill Interaction for RMS Glideslope Angle Error for Transfer Trials 6000 Feet to the Ramp.

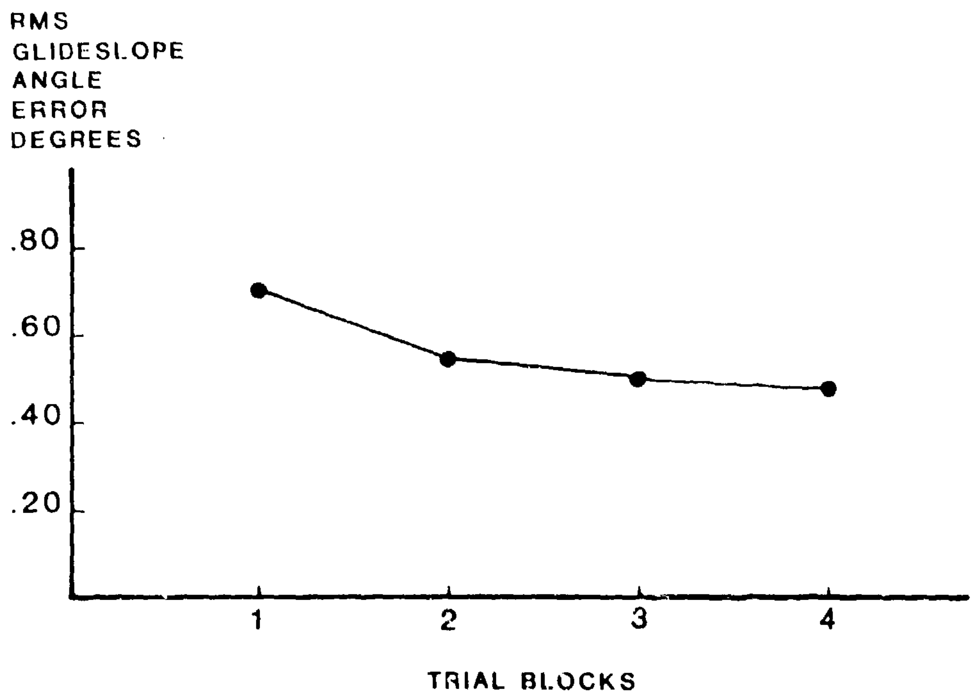

Figure 11. Graph of RMS Glideslope Angle Error By Trial Blocks for Transfer Trials 6000 Feet to the Ramp.

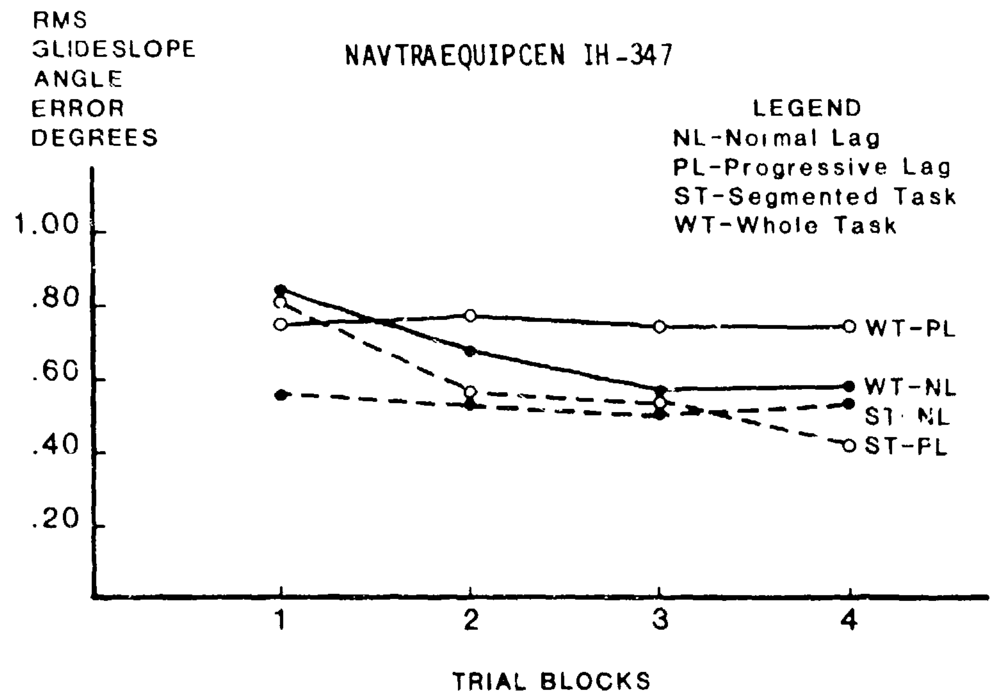

Figure 12. Graph of Blocks by Task by Lag Interaction for RMS Glideslope Angle for Transfer Blocks 6000 Feet to the Ramp.

three of the other groups on block one such that segmented task - normal lag was the superior group on block one. These latter two groups were not significantly different from one another on block one. On block two the situation changed in that the two segmented conditions merged and were not different from one another, but both groups were superior to the whole task groups which were significantly different from each other. On block two the whole task - progressive lag condition was the worst group having shown a trend toward greater error. On block three, the trend continued with the whole task - progressive lag group exhibiting significantly poorer performance than the other three with these latter three groups not significantly different from one another. Block four shows the same result as block three with the exception that the segmented task - progressive lag condition was the superior group, being significantly different from the other three. The next best conditions were the segmented task - normal lag and the whole task - normal lag conditions which were not different from one another. The worst condition on block four was the whole task - progressive lag condition which showed little improvement over the four blocks of transfer trials.

RMS Glideslope Angle Error - Last 1000 Feet

The next analysis to be presented was performed on the RMS glideslope angle error scores for the last 1000 feet of the approach, which was the phase immediately preceding landing. Table 12 is the analysis summary table for this dependent variable. Generally, the pattern of results was the same as that previously shown for the whole 6000 foot approach. The task manipulation exhibited a statistically significant main effect ($F=5.13$, $p < .05$) as did the motor skill factor ($F=6.47$, $p < .05$). The direction of these differences was the same as for the 6000 foot approach with the segmented task being superior to the whole task group and high motor skill superior to low motor skill (Table 13). The interaction between motor skill and lag was also significant

TABLE 11
MEANS OF RMS GLIDESLOPE ANGLE FOR BLOCKS
BY TASK BY LAG INTERACTION FOR TRANSFER
TRIAL BLOCKS 6000 FEET TO THE RAMP

GROUP	TRIAL BLOCKS				
	1	2	3	4	MEAN
Whole Task Normal Lag					
Raw Score	.84	.68	.55	.57	.66
Log (X+1)	.26	.21	.17	.19	.21
Whole Task Progressive Lag					
Raw Score	.74	.77	.74	.74	.75
Log (X+1)	.23	.25	.23	.24	.24
Segmented Task Normal Lag					
Raw Score	.56	.53	.51	.52	.53
Log (X+1)	.18	.18	.17	.18	.18
Segmented Task Progressive Lag					
Raw Score	.82	.55	.52	.43	.58
Log (X+1)	.24	.18	.17	.15	.18

TABLE 12
ANALYSIS OF VARIANCE SUMMARY TABLE
FOR LOG OF RMS GLIDESLOPE ANGLE FOR
TRANSFER DATA 1000 FEET TO THE RAMP

SOURCE	df	MS	F
Between Subjects			
Task (T)	1	.1189	5.13*
Lag (L)	1	.0223	< 1
Motor Skill (M)	1	.1501	6.47*
TXL	1	.0063	< 1
TXM	1	.0055	< 1
LXM	1	.1377	5.94*
TXLXM	1	.0012	< 1
Error	31	.0232	
Within Subjects			
Blocks (B)	3	.0342	5.33**
BXT	3	.0021	< 1
BXL	3	.0015	< 1
BXM	3	.0184	2.88*
BXTXL	3	.0121	1.90
BXTXM	3	.0193	3.01*
BXLXM	3	.0063	< 1
BXTXLXM	3	.0081	1.26
Error	93	.0064	

*$p < .05$
**$p < .01$

TABLE 13
MEANS OF RMS GLIDESLOPE ANGLE FOR
TRANSFER TRIAL BLOCKS FOR TASK AND
MOTOR SKILL 1000 FEET TO THE RAMP

GROUP	TRIAL BLOCKS 1	2	3	4	MEAN
			Task		
Whole					
Raw Score	1.45	1.38	1.18	1.31	1.33
Log (X+1)	.35	.32	.28	.30	.31
Segmented					
Raw Score	1.18	.91	.85	.75	.92
Log (X+1)	.30	.26	.25	.23	.26
			Lag		
Normal					
Raw Score	1.28	1.03	.90	.86	1.02
Log (X+1)	.32	.28	.24	.26	.27
Progressive					
Raw Score	1.36	1.27	1.13	1.20	1.24
Log (X+1)	.34	.30	.28	.27	.30
			Motor Skill		
High					
Raw Score	1.18	1.07	.83	.64	.93
Log (X+1)	.30	.28	.23	.20	.25
Low					
Raw Score	1.47	1.23	1.21	1.45	1.34
Log (X+1)	.36	.30	.30	.32	.32
			Blocks		
Raw Score	1.32	1.15	1.02	1.03	
Log (X+1)	.33	.29	.26	.26	

	Grand Mean	Standard Deviation
Raw Score	1.13	.84
Log (X+1)	.28	.12

($F=5.94$, $p < .05$). The cell means for this interaction are given in Table 14 and a graph of this interaction is shown in Figure 13. Comparison of means showed that the interaction between motor skill and lag manipulation was due to a significant difference between the lag conditions for the low motor skill group upon transfer ($F=5.67$, $p < .05$) while there was no difference in the performance of the high motor skill subjects between the two lag conditions.

In addition to the between-subjects effects, significant effects were found for the within-subjects factor of blocks ($F=5.33$, $p < .01$) and for the two and three way interactions of blocks by motor skill ($F=2.88$, $p < .05$) and blocks by task by motor skill ($F=3.01$, $< .05$). The Newman-Keuls test of the block means showed that the main effect of block was due to a significant difference between performance on block one and blocks two, three, and four. Transfer performance was significantly worse on block one than on the other three blocks and there was no significant difference in performance on blocks two through four. The significant interaction between motor skill and transfer trial blocks is illustrated in Figure 14. Both groups tended toward reduced error on blocks one and two. The low motor skill group tended to diverge from this trend leveling off on block three and exhibiting greater errors on block four while the high motor skill group continued to show reduced errors on blocks three and four. The blocks by task by motor skills interaction (Table 15) indicates that the transfer task performance over trial blocks was best characterized by the task motor skill groupings. The trend indicated that the task main effect was most prevalent on the first two blocks and that the whole task - high motor skill group began to show reduced errors such that it was approaching the performance of the segmented groups by the third trial block. The whole task - low motor skill group, by contrast, did not show quite as much a reduction in errors across transfer trial blocks, but instead showed a trend toward increased errors so that by the fourth trial block the whole task - low motor skill subjects were far worse than the other three groups. This is illustrated in Figure 15.

RMS Line-Up Error - 6000 Foot Approach

An analysis similar to that performed on the glideslope angle error data was performed on the dependent variable of RMS line-up error for the whole 6000 foot approach. Table 16 is the analysis of variance summary table for this analysis. No significant effects were revealed by this analysis.

RMS Line-Up Error - Last 1000 Feet

Table 17 presents the analysis summary table for the RMS line-up error data for the last 1000 feet of the approach for the transfer task. Three significant main effects were found, task ($F=3.98$, $p < .05$), lag ($F=4.17$, $p < .05$), and blocks ($F=3.55$, $p < .05$). Inspection of the means for RMS line-up for the last 1000 feet (Table 18) shows that the task effect was due to the segmented task subjects performing better on line-up than the whole task subjects while the subjects trained under the progressive lag condition

TABLE 14
MEANS OF RMS GLIDESLOPE ANGLE FOR
TRANSFER BLOCKS FOR MOTOR SKILL
BY LAG 1000 FEET TO THE RAMP

MOTOR SKILL

	HIGH	LOW
Lag		
Normal	1.05	.97
(Transformed)	.28	.30
Progressive	.81	1.67
(Transformed)	.27	.40

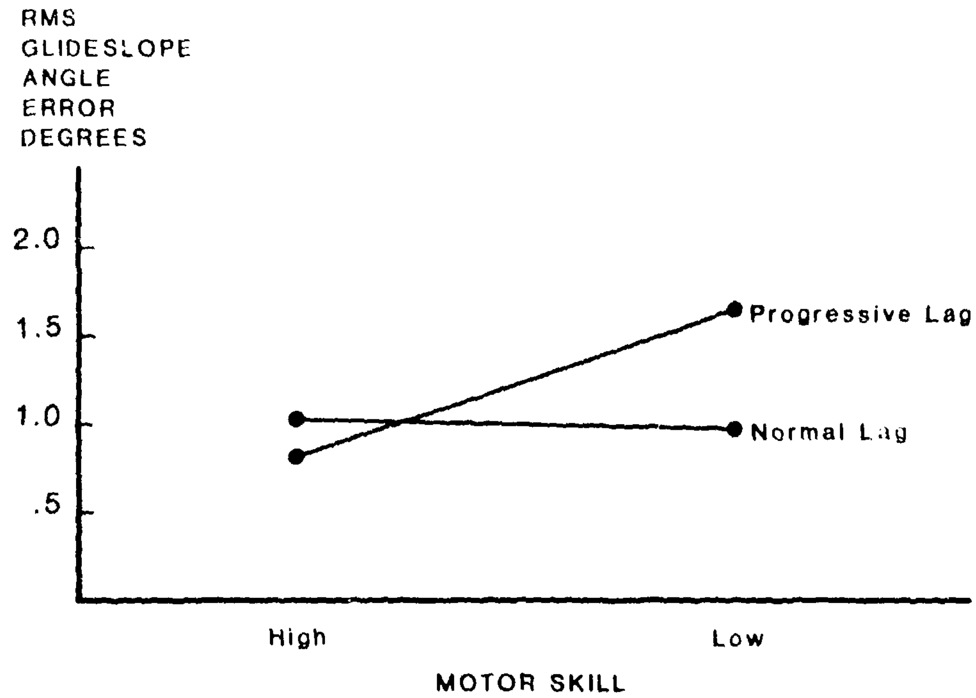

Figure 13. Graph of the Lag by Motor Skill Interaction for RMS Glideslope Angle Error for Transfer Trials for 1000 Feet to the Ramp.

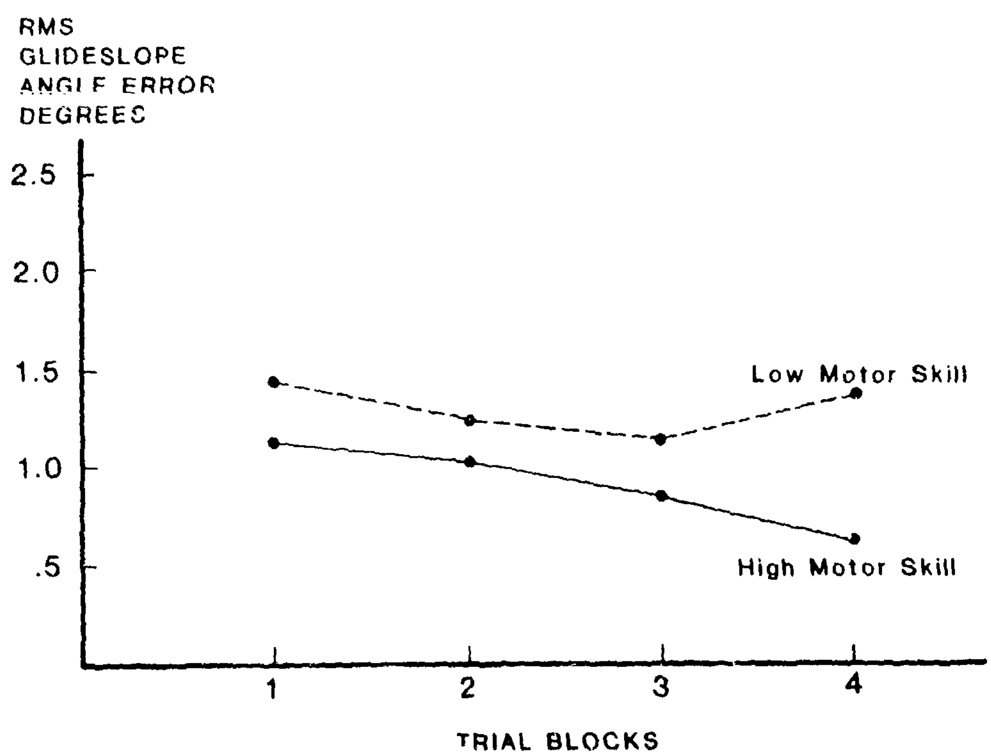

Figure 14. Graph of the Blocks by Motor Skills Interaction for RMS Glide-slope Angle for Transfer Trials for 1000 Feet to the Ramp.

TABLE 15
MEANS OF RMS GLIDESLOPE ANGLE FOR BLOCKS
BY TASK BY MOTOR SKILL INTERACTION FOR
TRANSFER TRIAL BLOCKS 1000 FEET TO THE RAMP

GROUP	TRIAL BLOCKS				
	1	2	3	4	MEAN
Whole Task High Motor Skill					
Raw Score	1.49	1.28	.96	.64	1.09
Log (X+1)	.35	.31	.24	.20	.28
Whole Task Low Motor Skill					
Raw Score	1.41	1.48	1.39	1.98	1.56
Log (X+1)	.36	.33	.32	.39	.35
Segmented Task High Motor Skill					
Raw Score	.87	.87	.71	.64	.77
Log (X+1)	.25	.25	.22	.20	.23
Segmented Task Low Motor Skill					
Raw Score	1.07	.94	.87	1.01	.97
Log (X+1)	.35	.26	.28	.25	.28

TABLE 16
ANALYSIS OF VARIANCE SUMMARY TABLE
FOR LOG OF RMS LINE-UP FOR TRANSFER
DATA 6000 FEET TO THE RAMP

SOURCE	df	MS	F
Between Subjects			
Task (T)	1	.0071	< 1
Lag (L)	1	.1265	1.65
Motor Skill (M)	1	.00352	< 1
TXL	1	.1880	2.41
TXM	1	.2134	2.73
LXM	1	.0158	< 1
TXLXM	1	.1655	2.12
Error	31	.0781	
Within Subjects			
Blocks (B)	3	.0231	1.34
BXT	3	.0042	< 1
BXL	3	.0113	< 1
BXM	3	.0210	1.22
BXTXL	3	.0019	< 1
BXTXM	3	.0132	< 1
BXLXM	3	.0058	< 1
BXTXLXM	3	.0107	< 1
Error	93	.0173	

TABLE 17
ANALYSIS OF VARIANCE SUMMARY TABLE FOR
LOG OF RMS LINE-UP FOR TRANSFER
DATA 1000 FEET TO THE RAMP

SOURCE	df	MS	F
Between Subjects			
Task (T)	1	.4219	3.98*
Lag (L)	1	.4422	4.17*
Motor Skill (M)	1	.1833	1.73
TXL	1	.0385	< 1
TXM	1	.0285	< 1
LXM	1	.2322	2.19
TXLXM	1	.0413	< 1
Error	31	.1060	
Within Subjects			
Blocks (B)	3	.0846	3.55*
BXT	3	.0208	< 1
BXL	3	.0021	< 1
BXM	3	.0298	1.25
BXTXL	3	.0147	< 1
BXTXM	3	.0120	< 1
BXLXM	3	.0104	< 1
BXTXLXM	3	.0102	< 1
Error	93	.0238	

$*p < .05$

TABLE 18
MEANS OF RMS LINE-UP FOR TRANSFER TRIAL BLOCKS BY GROUP 1000 FEET TO THE RAMP

GROUP	TRIAL BLOCKS 1	2	3	4	MEAN
Task					
Whole					
Raw Score	25.59	23.02	22.79	21.58	23.24
Log (X+1)	1.35	1.23	1.24	1.25	1.27
Segmented					
Raw Score	20.59	17.94	14.48	15.31	17.08
Log (X+1)	1.21	1.19	1.10	1.16	1.17
Lag					
Normal					
Raw Score	18.73	16.14	15.53	16.52	16.73
Log (X+1)	1.21	1.15	1.12	1.18	1.17
Progressive					
Raw Score	27.36	24.73	21.79	20.44	23.58
Log (X+1)	1.36	1.28	1.22	1.22	1.27
Motor Skill					
High					
Raw Score	18.31	17.82	17.42	18.08	17.91
Log (X+1)	1.21	1.19	1.14	1.19	1.18
Low					
Raw Score	28.25	23.42	20.13	19.00	22.70
Log (X+1)	1.40	1.24	1.21	1.21	1.26
Blocks					
Raw Score	20.59	17.94	14.48	15.31	
Log (X+1)	1.29	1.22	1.17	1.20	

	Grand Mean	Standard Deviation
Raw Score	20.24	13.36
Log (X+1)	1.22	.22

performed significantly worse than those trained on the normal lag condition. The Newman-Keuls test indicated that the blocks effect was due to the significant difference between block one and the other three transfer trial blocks. Performance on block one was the poorest and improved on blocks two, three, and four with no differences between performance on the latter three blocks. Figure 16 is a graph of the line-up performance across the four transfer trial blocks.

RMS Angle of Attack Error - 6000 Foot Approach

Table 19 is the analysis summary table for the RMS angle of attack error for the 6000 foot approach. No significant effects were uncovered for the between- subjects factors while the within-subjects factor of blocks did reach significance ($F=3.23$, $p < .05$). The Newman-Keuls test showed that this significant effect was due to the difference between transfer task performance on block one and the other three blocks.

RMS Angle of Attack Error - Last 1000 Feet

As shown by the analysis summary presented in Table 20, there were no significant effects for the dependent variable of RMS angle of attack error for the last 1000 feet of the approach.

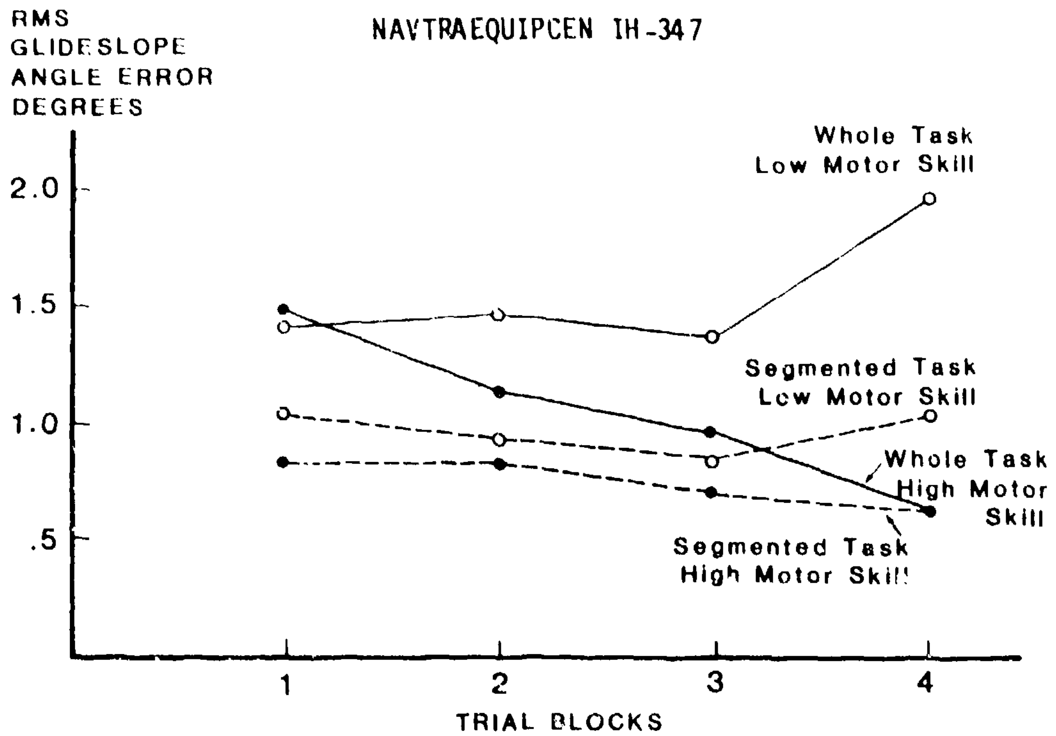

Figure 15. Graph of Blocks by Task by Motor Skill Interaction for Transfer Trial Blocks 1000 Feet to the Ramp.

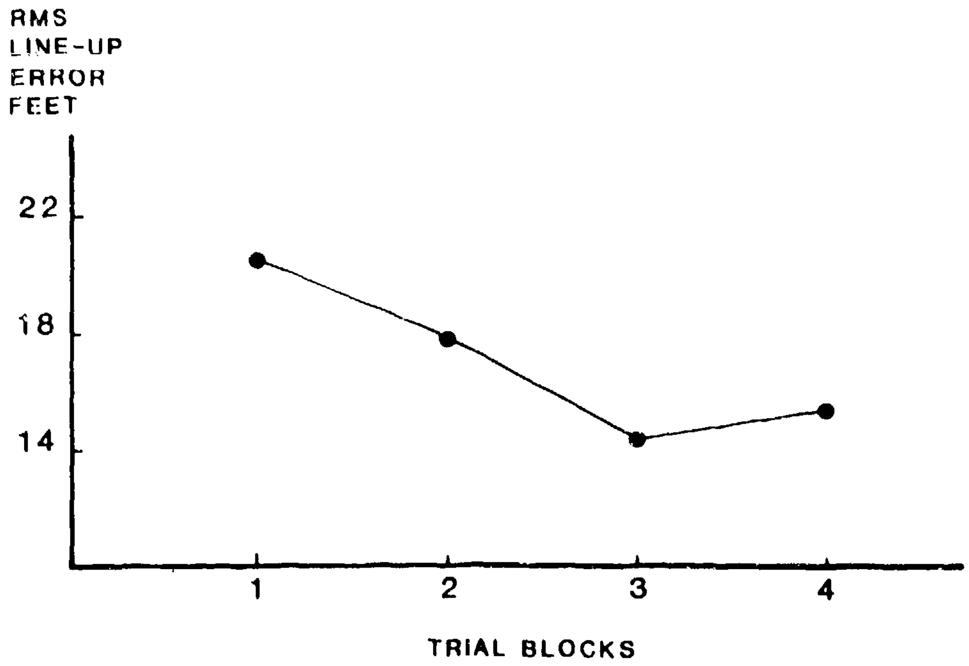

Figure 16. Graph of RMS Line-Up Error Across Transfer Trial Blocks 1000 Feet to the Ramp.

TABLE 19
ANALYSIS OF VARIANCE SUMMARY TABLE
FOR LOG OF RMS ANGLE OF ATTACK FOR
TRANSFER DATA 6000 FEET TO THE RAMP

SOURCE	df	MS	F
Between Subjects			
Task (T)	1	.0071	< 1
Lag (L)	1	.0218	2.79
Motor Skill (M)	1	.0257	3.30*
TXL	1	.0012	< 1
TXM	1	.0061	< 1
LXM	1	.0079	1.01
TXLXM	1	.0279	3.58*
Error	31	.0877	
Within Subjects			
Blocks (B)	3	.0027	3.23**
BXT	3	.0097	1.14
BXL	3	.0007	< 1
BXM	3	.0002	< 1
BXTXL	3	.0012	1.43
BXTXM	3	.0004	< 1
BXLXM	3	.0010	1.18
BXTXLXM	3	.0010	1.18
Error	93	.00085	

*p < .10
**p < .05

TABLE 20
ANALYSIS OF VARIANCE TABLE
FOR LOG OF RMS ANGLE OF ATTACK FOR
TRANSFER DATA 1000 FEET TO THE RAMP

SOURCE	df	MS	F
Between Subjects			
Task (T)	1	.0148	< 1
Lag (L)	1	.0902	3.43*
Motor Skill (M)	1	.0581	2.21
TXL	1	.0005	< 1
TXM	1	.0021	< 1
LXM	1	.0204	< 1
TXLXM	1	.0886	3.37*
Error	31	.0263	
Within Subjects			
Blocks (B)	3	.0077	2.02
BXT	3	.0022	< 1
BXL	3	.0021	< 1
BXM	3	.0017	< 1
BXTXL	3	.0063	1.64
BXTXM	3	.0028	< 1
BXLXM	3	.0039	1.05
BXTXLXM	3	.0004	< 1
Error	93	.0038	

*p < .10

SECTION IV

DISCUSSION

TRAINING DATA

A summary of the training data analysis is presented in Table 21. The results for training illustrate that learning did take place, as demonstrated by the significant blocks effect on the three dependent variables. In addition to this evidence, the blocks by task interaction (see Figures 5 and 8) shows that there is a positive learning trend for the whole task group across the training phase of the experiment on glideslope and line-up performance.

The segmented task group does not seem to exhibit the same apparent learning trend as displayed by the whole task group across the entire training phase of the experiment. Learning trends may not be apparent because the segmented task subjects were required to perform qualitatively different tasks during training. The data which illustrate such positive learning trends for the segmented task groups are the comparisons within each of the 16 trial sessions where the same task was practiced. Figures 5 and 8 show this trend toward reduced errors when comparisons are made between blocks 1 and 2 (the 2000 foot segment), blocks 3 and 4 (the 4000 foot segment), and blocks 5 and 6 (the entire 6000 foot approach). All of these comparisons indicate reductions in error on the last 1000 feet within the sessions where the same task segment was practiced which can be taken as evidence of learning.

Aside from general learning trends, there were also differences due to the training manipulations. The task manipulation exhibited a fairly strong effect on glideslope performance and a marginal effect on line-up, reflecting an advantage for the segmented task groups (see Tables 2 and 5). These comparisons were for the last 1000 feet of the approach where the subjects in the segmented groups were at a decided advantage given that they started at the 2000 foot point (blocks 1 and 2 of training). The segmented task subjects had the advantage of a better start and a chance to practice the more critical aspect of the task early in training. When both task groups became comparable during training blocks 5 and 6, where both groups are flying from 6000 feet, there is a tendency for the segmented group to assert its superiority and outperform the whole task group toward the end of training.

The lag manipulation appeared to have had little impact on training with a marginal but nonsignificant effect on angle of attack tracking with the progressive lag group superior to the normal lag group. This manipulation was not as successful in aiding training as was anticipated. The use of a progressive lag manipulation was thought likely to aid trainee performance since it followed a successive approximation type of program. This evidence indicates that the levels of progressively advanced lag may have been inappropriately set. The range of lag available for manipulation was limited by the practical constraints of the system. Instantaneous system response was not possible and any lag longer than that inherent in the transfer system would have been inappropriate.

TABLE 21
F-RATIOS OF SIGNIFICANT EFFECTS FOR
TRAINING DATA ACROSS DEPENDENT
VARIABLE FOR FINAL 1000 FEET

	Dependent Variable		
Source	Glideslope Angle	Line-up	Angle of Attack
Task (T)	5.87**	3.54*	ns
Lag (L)	ns	ns	3.67*
Motor Skill (M)	6.38**	8.37***	5.13**
Blocks (B)	2.80**	4.96***	3.36**
BXT	11.38***	10.41***	ns
BXTXL	2.68**	ns	ns

*p < .10
**p < .05
***p < .01

The motor skill variable had a strong and pervasive effect across all three dependent variables, as expected, with high motor skill subjects performing better than low motor skill subjects during training. This result is consistent with earlier findings (Lintern and Kennedy, 1982).

Aside from the main effects and the task by blocks interaction, a significant three-way interaction was found for blocks by task by lag on the glideslope measure. This interaction indicated that the trend toward increased errors for the segmented groups was due to the change from the initial reduced lag to the more sluggish intermediate setting for the Segmented Task-Progressive Lag group (see Figure 7). Not only were these subjects required to adjust to a longer approach segment, but they were also faced with an adaptation to a longer lag between the throttle control and the change in the FLOLS.

Generally, the results for the training data show that the training task was appropriate for the level of subjects employed and that the amount of training was sufficient to result in learning. The independent variables were set at the appropriate level with the possible exception of the lag manipulation which was constrained by practical considerations. In a transfer of training experiment, it is important that the subjects show some evidence of learning on the dependent measures before an assessment of the transfer of training can take place. The evidence from the training phase of this experiment indicated that the necessary conditions of learning did take place and, thus, an examination of transfer effects is appropriate.

TRANSFER DATA

Table 22 lists the significant effects for each of the experimental variables for the transfer session. Significant main effects were found for ask type on both glideslope measures and on line-up for the last 1000 feet of the transfer task. Significant main effects were also found for motor skill on both glideslope measures and for the lag manipulation on line-up for the last 1000 feet of the transfer task.

In addition to these main effects, the between subjects interaction of lag by motor skill was significant as were the three interactions of blocks by motor skill, blocks by task by lag, and blocks by task by motor skill.

Task Effects

A substantial effect was found for the task manipulation. Subjects trained under the task segmentation condition did better on transfer to the whole task than those trained with the whole task. These results are consistent with the results of past experiments using a backward chaining scheme to present a segmented part-task training strategy (Bailey, Hughes, and Jones, 1980).

One of the most obvious principles of part-task training is that intensive practice should be allowed on the key aspects of the task that are the most difficult. Schneider (1982), in a recent experiment, illustrated how intensive practice on the most difficult elements of the air intercept

TABLE 22
F-RATIOS OF SIGNIFICANT EFFECTS FOR
TRANSFER DATA ACROSS DEPENDENT VARIABLES

Source	Dependent Variable: Glideslope Angle 6000 ft	Glideslope Angle 1000 ft	Line-up 6000 ft	Line-up 1000 ft	Angle of Attack 6000 ft	Angle of Attack 1000 ft
Task (T)	6.70**	5.13**	ns	3.98**	ns	ns
Lag (L)	ns	ns	ns	4.17**	ns	3.43*
Motor Skill (M)	5.72**	6.47**	ns	ns	3.30*	ns
LXM	4.65**	5.94**	ns	ns	ns	ns
TXLXM	ns	ns	ns	ns	3.58*	3.37*
Blocks (B)	4.78***	5.33***	ns	3.55**	3.23**	ns
BXM	ns	2.88**	ns	ns	ns	ns
BXTXL	4.70***	ns	ns	ns	ns	ns
BXTXM	ns	3.01**	ns	ns	ns	ns

*$p < .10$
**$p < .05$
***$p < .01$

controller's task led to better performance than practice on the whole task. In the case of the present experiment, however, the difficult elements of task performance (the last 1000 feet of the approach) were practiced equally by all subjects. The segmented task subjects profited by practicing the difficult elements in isolation and actually had less total time in overall glideslope tracking than the whole task subjects.

There are two possible explanations for the effectiveness of the segmentation technique: either it allows for the opportunity to practice the critical aspects of the task in isolation free from the ambiguities of earlier t[illegible]formance or the backward chaining nature of the technique makes it ea[illegible] for subjects to relate the reward for task performance (knowledge of re[illegible]lts) with successful task performance.

The subjects in the segmented task group practiced the difficult aspects of the task isolated from the ambiguities introduced by earlier requirements. They started on the glideslope, and any errors that occurred were related to the segment they were practicing while the whole task subjects were still correcting earlier errors. As stated by Adams (1978) knowledge of results about errors, how they happen, and what to do in order to correct them is important to the development of a standard of correctness which guides the performance of a perceptual-motor behavior. To the extent that information about the source of errors is abstracted or obscured, ambiguity is introduced and learning is slowed.

The second explanation for the effectiveness of the segmentation technique would imply that learning a terminal task like carrier landings is an intrinsically backward chaining process. While the subject gets rewarded in the form of knowledge of results throughout task performance, the most potent rewarding event occurs at touchdown. This terminal knowledge of results may s[illegible] behavior immediately prior to it, but earlier behavior may not be shaped [illegible]ctively. The performance elicited by the intermediate knowledge of results may permit bad habits to be developed during the earlier segments which must be overcome. Since the subjects in the segmented condition were more likely to experience the reward sooner in training, they were more likely to be reinforced for performing the task and, therefore, developed response patterns which were more stable and correct.

Each of these explanations suggest different approaches to the training of perceptual-motor skills. The first explanation would lead to the practice of the difficult elements in isolation with its aim to clarify relationships, remove ambiguities, and develop consistencies between error conditions and responses. The second explanation would suggest either that a backward chaining technique be implemented or that the intermediary feedback be made more potent, perhaps through the use of augmented feedback as employed by Lintern (1980).

Future research should aim to discover why the segmentation technique works. Is the effect due to the reward being linked more closely with correct performance under segmented conditions or is it because this form of practice allows for the isolation of critical relationships free from the ambiguity of earlier errors? This last hypothesis is partially supported by the present

data since the segmented task subjects began to perform better than the whole task subjects on their second block of whole task approaches (see Figure 5).

In this experiment, both the difficult elements of the task and the terminal phase of task performance were close together in time, so a good test of which of these propositions holds was not possible. The value of training research lies in not merely knowing that something is effective, but in discovering the basic principles which control its effectiveness. Only by understanding these principles will it be possible to generalize to other tasks. In order to get a clearer test of which of these factors is responsible for the segmentation technique's value, a task should be selected for investigation where the difficult elements are remote from the terminal phase of task performance. Using such a task, an experiment could be performed where a backward chaining technique could be pitted against a part-task technique where concentrated practice of the critical elements was allowed.

Whatever the operative element, it is apparent that the segmentation technique was a powerful manipulation in this experiment. The effect of this technique was strong enough to overcome the influence of such powerful and well established transfer principles as similarity and practice (Holding 1965). The similarity principle asserts that the highest transfer is most likely to occur when training is conducted under conditions which are identical to the transfer task, while the practice notion states that the best transfer is likely when the training situation allows for extensive practice on the control activity. In the case of the present experiment, the whole task group was trained on a task which was identical to the transfer task and was allowed to practice the control task for a longer period of time than the segmented task groups but the segmented task group was able to outperform the whole task group on transfer.

Lag Effects

The only significant effect for the progressive lag manipulation on transfer was found on line-up performance, but the result was in the opposite direction of that predicted. Subjects trained with the progressive lag training strategy actually did worse on line-up than those trained with the normal throttle response. This result was in line with previous research which showed no benefit for systems modification to aid in the training of a perceptual-motor skill (Levine, 1953; Lintern and Gopher, 1978). While this prediction was evident, this experiment tried to make such a manipulation effective by using a successive approximation technique and by giving supplemental information about the nature of the lag changes during training. As stated previously, the lack of success for the progressive lag manipulation may be due to the practical constraints of manipulating this variable during training.

The results for transfer imply that the progressive lag manipulation was detrimental to line-up performance. No explanation for this finding is readily apparent since the progressive lag manipulation was designed to aid glideslope performance and not line-up. Perhaps the emphasis placed upon the glideslope portion of the task by the progressive lag technique led to a

neglect of the line-up tracking aspect of the task so that the progressive lag subjects did not begin to concentrate on line-up tracking until the transfer task was performed.

The blocks by task by lag interaction for the glideslope measure for the 6000 foot approach (Figure 12) shows that the combination of whole task and progressive lag on training served to undermine the subjects' chances to perform well on transfer. The segmented task-normal lag subjects appear to have been fully trained from the start of transfer while subjects in the whole task-normal lag and segmented task-progressive lag began transfer poorly, but quickly improve to a fully trained level of performance. The whole task-progressive lag subjects, by contrast, seemed to have built up a set of habit patterns during training which were difficult to overcome. These subjects began transfer at a poor level of performance and did not improve over the course of transfer. Somehow coping with learning the whole task and adapting to the change in lag must have led to a strategy that inhibited these subjects from improving their performance to the level of the other three groups. The initial superiority of the segmented task-normal lag group upon transfer and the evidence that this group's error was lowest during training implies that training under the easiest training manipulation led to the best performance on initial transfer.

In addition, this interaction supports the notion that the best transfer is yielded when training is conducted under easy conditions for transfer to a difficult criterion (Holding, 1965).

Motor Skill Effects

A significant effect was observed for the motor skill variable on both of the glideslope measures. In each case the high motor skill subjects performed better than the low motor skill subjects. This outcome is supportive of recent evidence that this measure is predictive of performance on perceptual-motor type tasks (Kennedy, Bittner, and Jones, 1981; Lintern and Kennedy, 1982). This variable was included to test the interaction between it and the training manipulations. The value of the main effect result is that it validates the use of the Atari Air Combat Maneuvering video game as a test of motor skill. Tests of this type could prove useful as selection tools or as covariates to aid in extracting variance due to individual differences in experimentation on perceptual-motor skills.

The interactions uncovered between the motor skill variable and the training manipulations illustrate how important knowledge about individual differences can be to the interpretation of the effects of training techniques. The lag by motor skill interaction showed that the progressive lag manipulation hurt the low ability subjects but had no effect on the high ability subjects. This means that low ability subjects may require a higher level of fidelity for control-display lags between training and transfer than high ability subjects. The question also arises as to what effect might be noted for the low ability students if they were to transfer from long lags to short lags as often happens when going from a simulator to an aircraft. The answer to this question could have important implications for simulator design since the reduction of delays in simulators to the level of high performance aircraft requires the use of faster, more expensive computer systems.

Another implication of motor skill level which would have gone unnoticed had it not been included is the effect motor skill had on performance across the transfer trials as shown by the blocks by motor skill interaction. Figure 14 shows that the low motor skill subjects performed more poorly on transfer and seemed to stop learning sooner that the high motor skill subjects.

A second interaction with transfer trial blocks which shows the power of the segmentation variable is the blocks by task by motor skill interaction. This interaction illustrates how subjects' transfer performance may be influenced by both the training technique employed and the subjects' ability. This is an example of an aptitude by treatment interaction sought after by instructional researchers (Cronbach and Snow, 1977). This type of finding is unprecedented in flight simulator training research. As shown in Figure 15, the low motor skill subjects seemed to tire near the end of transfer and did not exhibit learning trends across transfer trials. This is in contrast to the whole task-high motor skill subjects who showed learning trends during transfer, at least to the level of the segmented task subjects who appear to be fully trained at the start of transfer. This finding shows that the segmented task training technique is the most effective way of influencing transfer. The high motor skill subjects seem to be able to overcome the disadvantage of training by the whole task method while low motor skill subjects cannot. Low motor skill subjects appear to be more susceptible to the influence of the bad habits they develop during training and do not seem to be able to overcome these response patterns in order to improve their transfer performance. These low motor skill subjects appear to be less adaptable than their high motor skill counterparts when adjusting to the transfer task.

The major finding of this study lies in the discovery that the segmented part-task training method has real value for assisting low aptitude subjects to perform on perceptual-motor tasks. A further contribution lies in the generation of plausible explanations for the effectiveness of the segmented technique together with suggestions for future research to expand its generalizability.

While the outcome of this experiment is encouraging, certain limitations to the generalizability of the results are noteworthy. Three major concerns which should be addressed when attempting to draw general conclusions from this experiment are: the characteristics of the subject population, the type of task used, and the within simulator nature of the experiment. The subjects employed in this experiment were selected from a population of college students while the group to whom the results of this experiment should be applied are military student pilots. The military student pilot population is a somewhat restrictive sample drawn from the pool of college graduates and differences may exist between these two populations. The task employed in this experiment was a specific, specialized flight task. It may differ from other types of tasks with respect to the degree of error tolerance allowed and the control strategy required. Conversely, the carrier landing task may share elements in common with other perceptual-motor tasks. Generalizability to other continuous perceptual-motor tasks which are focused upon some terminal goal is possible.

One final limitation to the external validity of this or any other experiment where both training and transfer occur in the simulator is that the assessment of criterion performance was not conducted in the aircraft. While actual transfer of training experiments are costly and dangerous, they represent the ultimate in determining the worth of simulator training technology and are preferred whenever cost will allow. The use of the simulator to assess transfer performance should not be taken lightly either, since flight simulator performance can be an adequate representation of piloting skill and presents the added convenience of more refined measures of performance than may be available in the aircraft.

Despite the factors which may limit the generality of these findings, certain statements can be made about part-task training for perceptual-motor skills based upon the results of this experiment. The analysis of previous research revealed that part-task training of complex, highly organized perceptual-motor skills was inferior to whole-task training. These studies relied upon the fractionation method as the technique for task subdivision. This experiment sought to illustrate the value of two other forms of task partitioning: simplification and segmentation.

The simplification technique, as implemented in this experiment, was not successful in influencing either training or transfer. The data indicate that the progressive lag manipulation, designed to simplify the task for training, did not result in a simpler training task than the normal lag condition. This evidence implies that the employment of a progressive lag technique does little to reduce errors during training. Requiring subjects to change responses while no changes occur in the stimulus does nothing to speed learning. This does not imply that simplification will not work in any case, but does indicate that a more fruitful approach may lie in the modification of stimulus elements when response requirements change as occurs when feedback is modified, such as through the use of augmented displays (Lintern, 1980).

The segmentation manipulation worked quite well in this experiment. In terms of the taxonomy presented earlier, it appears that the pure segmentation approach led to a somewhat simpler training condition than any other (see Figure 6). In a sense the segmentation technique is also a simplification technique of a special kind which results in lower errors during training and improved transfer performance over whole task training.

The outcome of this experiment indicates that when a continuous multidimensional perceptual-motor task is to be trained, the use of a part-task technique which will divide the task into meaningful segments is possible. Furthermore, this technique can actually lead to better transfer of training over practice of the whole task with less total practice time, and is particularly beneficial for low aptitude trainees.

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APPENDIX A
SPECIAL INSTRUCTIONS

SPECIAL SECTION - WHOLE TASK

You have been instructed in how to fly the carrier landing approach from 6000 feet to touchdown. You will now be allowed to practice landings in the simulator for training purposes. This training will consist of three simulator sessions of 16 approaches each. After each approach, you will be given instructional feedback in the form of a verbal critique of your technique along with suggestions for how to improve your glideslope performance. Between each simulator session you will be given a short break.

Once you are placed in the simulator cockpit, you will be allowed to practice two landings without any instructional feedback. This is being done to familiarize you with the nature of the task you will ultimately be required to perform. After these familiarization trials, training will commence.

SPECIAL SECTION - SEGMENTATION

You have been instructed in how to fly the carrier landing approach from 6000 feet to touchdown. For your practice sessions, however, you will be presented with the task in three progressive sections. Your goal is to learn to fly the entire 6000 foot approach but, for training purposes you will practice it in segments.

For your first training session, you will be positioned on the glideslope 2000 feet from the carrier. You will be given 16 opportunities to practice the task from this distance. After each approach you will be given feedback about how you have performed along with information about how to improve your technique. For the next 16 practice trials, you will fly from 4000 feet to the carrier and for the final 16 landings, you will fly from 6000 feet to the carrier.

Once you are placed in the simulator cockpit, you will be allowed to practice two landings from 6000 feet. This is being done to familiarize you with the nature of the task you will ultimately be required to perform. After these familiarization trials, training will commence.

SPECIAL SECTION - PROGRESSIVE LAG

You have been instructed in how to fly the carrier landing approach from 6000 feet to touchdown. As was stated in the instructions, the aircraft will respond rather sluggishly to throttle inputs and you may be tempted to over control with the throttle since glideslope corrections do not take effect immediately. This is due to the delay which exists between throttle changes and aircraft response. For some of your training sessions, however, the delay between throttle responses and meatball movements will be reduced. For the first 16 landings, you will begin the approach from 6000 feet from the carrier. On these 16

landings, the simulator will be modified in a way which will make the aircraft respond to power inputs more rapidly than it does normally. For the second session of 16 landings, you will begin the approach at 6000 feet from the carrier but the throttle's response will not be quite as rapid as at first. On the final 16 landings, you will be set up 6000 feet from the carrier with the lag between throttle changes and FLOLS response as it is on the real task. After each approach, you will be given feedback about how you have performed and how to improve your technique.

Once you are placed in the simulator cockpit, you will be allowed to practice two landings from 6000 feet with the normal throttle delay. This is being done to familiarize you with the nature of the task you will ultimately be required to perform. After these familiarization trials, training will commence.

SPECIAL SECTION - SEGMENTATION AND PROGRESSIVE LAG

You have been instructed in how to fly the carrier landing approach from 6000 feet to touchdown. As was stated in the instruction, the aircraft will respond rather sluggishly to throttle inputs and you may be tempted to over control with the throttle since glideslope corrections do not take effect immediately. This is due to the delay which exists between throttle changes and aircraft response. For some of your training sessions, however, the delay between throttle responses and meatball movements will be reduced. In addition, you will be presented with the task in three segments. For the first 16 landings, you will begin the approach from 2000 feet from the carrier. On these 16 landings, the simulator will be modified in a way which will make the aircraft respond to power inputs more rapidly than it does normally. For the second session of 16 landings, you will begin the approach at 4000 feet from the carrier but the throttle's response will not be quite as rapid as at first. On the final 16, lag between throttle changes and FLOLS response will be as it is on the real task. After each approach, you will be given feedback about how you have performed and how to improve your technique.

Once you are placed in the simulator cockpit, you will be allowed to practice two landings from 6000 feet with the normal throttle delay. This is being done to familiarize you with the nature of the task you will ultimately be required to perform. After these familiarization trials, training will commence.

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Warminster, PA 18974

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Indiana 46216

Mr. Heinz Friedrich 1
Chief, Flight Simulation Branch
Dornier GmbH
Postfach 1426
D7990 Friedrichshafen FRG

Mr. Clarence A. Fry 1
U.S.Army Human Engineering Lab
Attn: DRXHE
Aberdeen Proving Ground
Maryland 21005

Dr. Richard F. Gabriel 1
Douglas Aircraft Co.
3855 Lakewood Blvd.
Long Beach, CA 90846

Dr. Ralph Haber 1
AFHRL/OTR
Williams AFB, AZ 85224

Dr. Genevieve Haddad 1
AFOSR/NL
Bolling AFB, D C 20332

Dr. Edward R. Jones 1
Chief, Human Factors Engr.
McDonell Douglas Corp
St. Louis, MO 63166

Mr. Charles E. Kaul 1
7101 Galgate Drive
Springfield, VA 22153

Dr. William J. King 1
Ergonomics Associates, Inc.
P. O. Box 20987
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Dr. Herschel W. Leibowitz 1
Professor of Psychology
614 Bruce V. Moore Building
Pennsylvania State University
University Park, PA 16802

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Redstone Arsenal, AL 35898

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Hawthorne, CA 90250

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Hughes Aircraft Corp
Building R-1
M/S C-320
Los Angeles, CA 90009

Dr. Robert T. Hennessy 1
Committee on Human Factors
National Research Council
2101 Constitution Ave.
Washington, D C 20418

Dr. William M. Hinton, Jr. 1
Allen Corporation
3751 Maguire Blvd., Suite 270
Orlando, FL 32803

Mr. James McGuinness 1
Person-System Integration
3012 Duke Street
Alexandria, VA 22314

Dr. Melvin D. Montemerlo 1
RTE-6
NASA Headquarters
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Dr. Frederick A. Muckler 1
Essex Corporation
741 Lakefield Rd., Suite B
Westlake Village, CA 91361

Dr. Kent A. Stevens 1
Department of Computer and
Information Science
University of Oregon
Eugene, OR 97403

Dr. Paul E. Van Hemel 1
Allen Corporation of America
401 Wythe Street
Alexandria, VA 22314

Mr. Donald Vreuls 1
Vreuls Research Corporation
68 Long Court, Suite E
Thousand Oaks, CA 91360

Mr. Lee Wooldridge 1
Vreuls Research Corporation
6568 University Boulevard
Orlando, FL 32807

Dr. Laurence Young 1
Dept. of Aeronautics
Massachusetts Inst. of Tech.
77 Massachusetts Ave.
Cambridge, MA 02139

Mr. J. Thel Hooks, Jr. 1
Dunlap and Associates
920 Kline St., Suite 203
La Jolla, CA 92037

Ms. Joyce Iavecchia 1
Naval Air Development Center
Code 6022
Warminster, PA 18974

Dr. Richard S. Jensen 1
Department of Aviation
Ohio State University
Box 3022
Columbus, OH 43210

Mr. Henry R. Jex 1
Systems Technology Inc.
13766 Hawthorne Blvd
Hawthorne, CA 90250

CDR, Naval Air Force 1
U. S. Atlantic Fleet
Attn: LCDR Robert Day
Norfolk, VA 23511

Dr. Wallace W. Prophet 1
Seville Research Corp
400 Plaza Bldg.
Pace Blvd. at Fairfield Dr
Pensacola, FL 32505

Professor Stanley N. Roscoe 1
Department of Psychology
New Mexico State University
Box 5095
Las Cruces, NM 88003

R. F. Schiffler 1
ASD/ENECH
Wright-Patterson AFB
Ohio 45433

Mr. Moses Aronson 1
3705 Wilder Lane
Orlando, FL 32804

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West Branch, IO 52358

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